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NEW ALLOCREADIDS (TREMATODA) FROM INDIAN MARINE FISHES. PART II. "NEW PARASITES OF THE GENUS *DECEMTESTIS* YAMAGUTI, 1934."

By Har Dayal Srivastava,

Offg. Helminthologist,

Imperial Institute of Veterinary Research, Muktesar, India.

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Three new species of the genus *Decemtestis* Yamaguti namely, *D. brevicirrus* n sp, *D. mehrai* n. sp. and *D. biacetabulata* n. sp. from marine fishes of the Bay of Bengal are described. *D. biacetabulata*, which is characterised by the presence of two protrusible acetabula,—a feature not known in any other trematode is the commonest distome infecting several fishes in the Bay of Bengal. Diagnosis of the genus *Decemtestis* and key to its species are given.

Genus Decemtestis Yamaguti, 1934

Yamaguti in 1934 described three new distomes from Japanese marine fishes and created a new genus *Decemtestis* for their reception. He further referred *Helicometrina azumae* Layman, 1930, to the genus *Decemtestis*, which

Manter in 1933 assigned to the genus *Rhagorchis* Manter, 1931, on account of close structural similarities and host relationships. In this paper are described three new parasites of the genus *Decemtestis* from fishes of the Bay of Bengal.

Decemtestis brevicirrus n. sp.

Host—*Sillago sihama* Gunther

Habitat—Intestine.

Locality—Puri, Bay of Bengal.

About two dozen specimens of this species were obtained from the gut of two out of thirty hosts examined. The parasites are elongated, oval in shape, with a smooth, feebly muscular body which lacks any marked power of contraction and expansion. In fixed preparations they measure 1·9–2·1 mm. in length and 0·68–0·82 in maximum breadth which occurs across the acetabular region. The subterminal oral sucker is spherical, 0·15-0·18 mm. in diameter with a fairly well developed musculature. The acetabulum is transversely oval in shape and measures 0·2-0·23 × 0·23–0·28 mm. in size. It is larger than the oral sucker and lies towards the end of the anterior half of body. The size ratio between the oral and ventral suckers is as 3: 4. The oral sucker opens posteriorly into a small, 0·05–0·1 mm. long prepharynx which is followed by a globular, muscular pharynx of 0·09–0·12 mm. size. The anterior margin of the pharynx is serrated. The short oesophagus, about the length of the pharynx, bifurcates into two long and uniformly broad caeca which extend upto the anterior half of the hindermost testis, i. e., posterior sixth or seventh part of body length.

The excretory bladder is a straight tube extending from the ovary to the hinder end. The excretory pore is terminal. The genital atrium is a shallow cup-shaped depression on the ventral body surface in level with the middle of pharynx, half way between the latter and the left body wall. The male and female openings lie separately in the genital atrium.

The male reproductive system consists of ten rounded or ovoid testes measuring 0·1-0·12 × 0·14-0·18 mm. in size and roughly arranged in the intercaecal space in two parallel rows one on either side of the median line in the hinder half of body, and extending upto the posterior ninth or tenth part of body. Rarely the testes lie irregularly in the intercaecal space. The cirrus sac is club-shaped, 0·38–0·47 × 0·05–0·07 mm. in size, extending obliquely from the genital atrium to a little less than

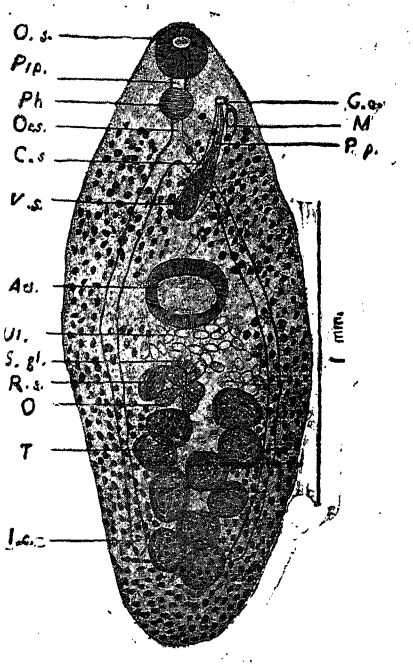

Fig I

Decemtestis brevicirrus, n. sp.

Lettering: *Acet.* Acetabulum, *C.s.* Cirrus sac, *G. a.* Genital atrium, *I.c.* Intestinal caecum, *M.* Metraterm, *O.* Ovary, *Oes.* Oesophagus, *O.s.* Oral sucker, *P. p.* Pars prostatica, *Ph* Pharynx, *Prp.* Prepharynx, *R.s.* Receptaculum seminis, *S.gl.* Shell glands, *T.* Testis, *Ut.* Uterus, *V. s.* Vesicula seminalis, *Vit.* Vitellaria.

half the distance between the intestinal bifurcation and acetabulum. It encloses a slightly coiled, elongated, bulb-shaped vesicula seminalis of 0·2–0·3 × 0·04–0·05 mm. size, a small tubular pars prostatica, 0·08–0·15 × 0·015 mm. surrounded by sparsely developed prostate gland cells, a short ductus ejaculatorius and a knob-shaped cirrus.

The ovary which measures 0·12 – 0·16 × 0·1 – 0·16 mm. in size is a small, deeply tetralobed structure situated almost in the median line close behind the anterior half of body. The receptaculum seminis is an oval bulb-shaped sac of 0·13–0·19 × 0·08–0·11 mm. size lying between the ovary and right caecum. The shell gland complex is situated just in front of the receptaculum seminis. Laurer's canal is present.

The vitellaria are enormously developed, follicular, extending laterally from the pharynx to the hinder end and meeting mesially in the

preacetabular and post-testicular regions. In the testicular region they invade to a little distance the intercaecal space. In a few specimens the vitellaria are interrupted laterally in the acetabular region. The uterus lies arranged in transverse coils in the intercaecal space between the testes and acetabulum. The terminal part of the ascending uterus is feebly muscular and runs along the left side of the cirrus sac. The eggs are oval in shape and yellow in colour, measuring 0·05 - 0·055 × 0·03 - 0·037 mm. in size.

Decemtestis brevicirrus, n. sp., differs from the Japanese species in the shape of body, position of acetabulum and gonads, length of cirrus sac which stops far short of the acetabulum, length of intestinal caeca and the disposition of the vitellaria.

Decemtestis mehrai, n. sp.

Host—*Sillago sihama* Günther.

Habitat—Intestine.

Locality—Puri, Bay of Bengal.

Eight specimens of this worm were recovered from the intestine of a fish examined in July 1935. The parasite has an elongated oval body, slightly tapering anteriorly in the preacetabular zone and broadly rounded off posteriorly. The feebly muscular body is completely devoid of scales or spines and measures 2·2—2·7 mm. in length and 0·73—0·94 mm. in maximum breadth across the acetabular region. The suckers are fairly muscular. The oral sucker is subterminal and measures 0·14—0·17 × 0·2—0·23 mm. in size. The ventral sucker measuring 0·28—0·33 mm. in diameter is situated at the junction of the first and middle thirds of body length. Prepharynx is small, 0·05—0·06 mm. long. The pharynx is muscular, cup-shaped and measures 0·08—0·1 × 0·1—0·12 mm. in size and is followed by a straight oesophagus, nearly twice its length. The intestinal caeca are straight, uniformly broad tubes extending up to the extreme hinder end. The excretory system is as in the other Indian species. The shallow cup-shaped genital atrium lies on the ventral surface in level with the base of oesophagus, half way between the latter and left body wall.

The testes, ten in number, are small, spherical bodies, measuring 0·08—0·011 mm. in diameter and arranged mostly in pairs in the intercaecal space extending from behind the receptaculum seminis to the posterior seventh part of body length. The cirrus sac is fairly long, 0·44 - 0·47 × 0·06 - 0·07 mm. club-shaped structure extending obliquely from the genital atrium

to the acetabulum. It encloses an elongated, bipartite, slightly convoluted vesicula seminalis, a small tubular pars prostatica surrounded by a few prostate gland cells, a small ductus ejaculatorius and cirrus.

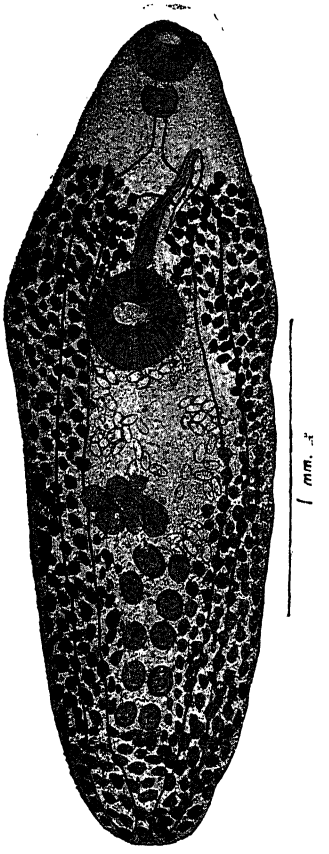

Fig II

Decemtestis mehrai, n. sp.

The ovary is deeply tetralobed, 0·17—0·21 × 0·18–0·21 mm. in size, intracaecal, pretesticular and slightly dextral. The receptaculum seminis is an elongated sac situated just in front of the testes in the median line to the left of the ovary. The shell gland complex lies immediately in front of the receptaculum seminis.

The vitellaria are extensively developed and consist of fairly large sized follicles extending laterally from intestinal bifurcation to the hinder end and meeting mesially in the post-testicular region and sometimes in the preacetabular zone also. The uterus runs in transverse coils between

the testes and acetabulum. The terminal part of the uterus runs in a straight course on the left of the cirrus sac and opens into the genital atrium through a poorly muscular metraterm. The oval, yellow eggs measure 0·06-0·063 × 0·03 – 0·037 mm. in size.

D. mehrai n. sp., differs from the three Japanese species and *D. brevicirrus* in the shape and size of body, and length of cirrus sac. In the length of its intestinal caeca it resembles the type species — *D. sillagonis* but differs from it in the position of the genital atrium, shape, size and position of gonads. From the other two Japanese species *D. mehrai* differs in the length of intestinal caeca, shape and position of gonads and disposition of vitellaria. It differs from *D. brevicirrus* in the length of caeca, position of genital pore and the size of testes and vitelline follicles.

Decemtestis biacetabulata n. sp.

Host—*Scomber micropeditorus* Rüppell.

Habitat—Intestine.

Locality—Puri, Bay of Bengal.

This species represents by far the commonest trematode infecting several fishes in the Bay of Bengal. The infection is often quite heavy. The parasites have a sub-cylindrical, muscular, elongated, uniformly broad body with broadly rounded off ends. The body is completely devoid of scales or spines and in permanent mount measures 1·4–2·1 mm. in length and 0·5 –0·7 mm. in maximum breadth. The oral sucker is a fairly muscular, spherical structure situated subterminally on the ventral surface. It is much smaller than the acetabula and measures 0·11–0·14 mm. in diameter. The ventral adhesive structure consists of two highly muscular, protrusible and concentrically situated suckers lying on the ventral surface at the junction of the first and middle thirds of body. The outer sucker measures 0·3 – 0·4 × 0·3 – 0·4 mm. in size, while the inner measures 0·18 – 0·24 × 0·16 – 0·22 mm. The prepharynx is very small, 0·03 — 0·04 mm. long, and opens posteriorly into a well-developed globular pharynx of 0·07 – 0·08 mm. diameter. The oesophagus is very short, measuring 0·08 mm. in length. The intestinal caeca are fairly broad in the preovarian region but become narrow in their postovarian course. The caeca run right upto the extreme hinder end of body. The excretory bladder is as in the other species. The genital atrium is situated on the ventral body surface

in level with the middle of the pharynx, half way between the latter and left body wall.

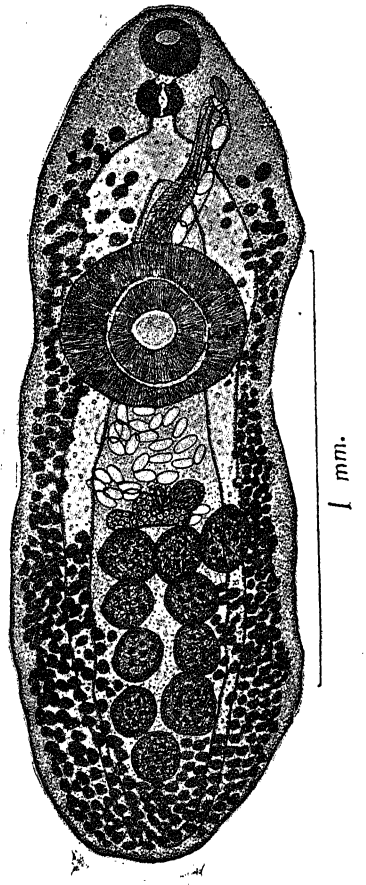

Fig. III A.

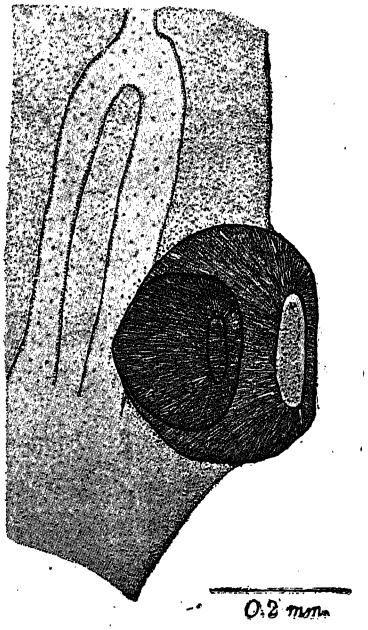

Fig. III B.

Fig. III A. *Decemtestis biacetabulata* n. sp.
Fig. III B. Lateral view of concentrically situated acetabula.

The testes, ten in number, are roughly spherical in shape, measuring 0·08 – 0·12 mm. in diameter. They are usually arranged in pairs in the intercaecal space in the posterior half of body extending from close behind the ovary to a little distance in front of the hinder end. The cirrus sac is a moderately long, club–shaped structure extending obliquely from the genital atrium to the middle of acetabula. It encloses a slightly coiled, bipartite vesicula seminalis, a small tubular pars prostatica surrounded by a few prostate gland cells, a small ductus ejaculatorius and a knob–like cirrus.

The ovary, 0·12 – 0·13 × 0·16 – 0·18 mm. in size, is deeply trilobed, rarely tetralobed, lying immediately in front of the testes in the median line a little behind the anterior half of body. The receptaculum seminis is sac–shaped, situated close in front of ovary slightly to the left side. Shell gland mass lies in the median line in level with the receptaculum seminis. Laurer's canal is present.

The vitellaria are profusely developed and are composed of small, innumerable follicles arranged laterally from the level of intestinal bifurcation to hinder end. The follicles meet mesially in the post-testicular region. The uterine coils are confined to the intercaecal space between the testes and acetabula. The eggs are oval, light yellow and 0·052 – 0·056 × 0·03 – 0·039 mm. in size.

The most characteristic feature of *D. biacetabulata* n. sp., is the presence of two protrusible, muscular and concentrically situated acetabula. Such a peculiar adhesive structure is not known to be present in any trematode so far studied. A somewhat similar structure is, however, present in the Amphistomes of the genus *Diplodiscus*. In the posterior extent of its cirrus sac this species resembles *D. ditrematis* but differs from it in the position of genital pore and gonads and the disposition of vitellaria.

Generic diagnosis of *Decemtestis* Yamaguti, 1934.

Alloceadiidae Stoss., 1903; Allocraediinae Looss, 1902. Body oval, elongated, fusiform or pyriform. Cuticle unarmed. Oral sucker subterminal and smaller than the acetabulum. Acetabulum single, rarely double, concentrically situated, muscular. Prepharynx present; pharynx well developed; oesophagus short; caeca simple, reaching nearly or upto the posterior end. Testes ten, usually in two longitudinal rows in the posterior half of body. Cirrus pouch well developed, of varying lengths, enclosing a slightly coiled elongated vesicula seminalis, a small tubular pars prostatcia surrounded by sparsely developed prostate gland cells, small ductus ejaculatorius and a small cirrus. Genital atrium shallow, situated half way between pharynx or oesophagus and left body wall. Ovary lobed, pretesticular, median or to a side. Receptaculum seminis and Laurer's canal present. Uterus pretesticular, intercaecal, rarely entering testicular zone. Vitellaria follicular, lateral, from level of pharynx, oesophagus or intestinal bifurcation to hinder end and sometimes meeting mesially iu the acetabular and post–esticular zones. Eggs not numerous, with or without polar prolongation.

Excretory bladder Y-shaped, bifurcating in front of testes. Intestinal parasites of marine fishes.

Key to the species of *Decemtestis* Yamaguti.

Acetabulum double.....*D. biacetabulata.*

Acetabulum single..... 1.

1. Cirrus sac extending beyond acetabulum..... 2.

   Cirrus sac not extending beyond acetabulum... 3.

2. Vitellaria interrupted laterally and eggs without polar prolongation..... *D. callionymi.*

   Vitellaria not interrupted laterally and eggs with polar prolongation..... *D. sillagonis.*

3. Cirrus sac stopping far short of acetabulum; caeca not extending into post-testicular zone... *D. brevicirrus*

   Cirrus sac extending upto anterior margin of acetabulum; caeca reach hinder end; vitellaria not meeting mesially in acetabuar zone...*D. mehrai,*

   Cirrus sac extending to middle of acetabulum; caeca reach hinder end; vitellaria meet mesially in the acetabular and preacetabular zone upto pharynx..... D. *ditrematis.*

I am deeply indebted to Dr. H. R. Mehra for his valuable help and suggestions and to our Director, Mr. F. Ware, F.R.C.V.S., I.V.S., for facilities and encouragement.

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SEXUAL DIMORPHISM AND POST-EMBRYONIC GROWTH IN *DIALEURODES DISSIMILIS* QUAINT. AND BAKER (HOMOPTERA, ALEURODIDAE).

By M. L. Roonwal

Zoology Department, Lucknow University

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1. For the first time sexual dimorphism has been shown to exist in the nymphs of a species of the Aleurodidae viz., *Dialeurodes dissimilis* Quaint. and Baker.

2. As shown by the ratio length/breadth, the male nymph is more elongate than the female.

3. The increase in size of the nymphs of each successive instar is greater in the female than in the male (except in the case of width increase in the second instar).

4. The total increase in size (length and width) is greater in the female than in the male.

5. The ratio of growth at any one moult is strikingly uniform in the two sexes (except in the width increase at the first moult).

6. The systematic importance of the recognition of the existence of sexual dimorphism among nymphs (particularly the pupa) of the Aleurodidae is discussed.

I. Introduction

Dimorphism in the size of adult insects is a widely known phenomenon, but similar differences in the early larval stages have received very little attention. It is well-known that adult Aleurodidae show a marked sexual dimorphism in, among other features, the size of the body (*vide* Table I) and the antennae (in *Dialeurodes dissimilis* the length of a female antenna is about 330 μ and of a male antenna 285μ), but in the early nymphal stages this phenomenon has been hitherto undescribed. The present paper would show that sexual dimorphism exists in the body size of all the nymphal stages of *Dialeurodes dissimilis* and probably of all the Aleurodidae.

In the nymphs of the sternorhynchous Homoptera, sexual dimorphism is not unknown. It is well seen in some of the Coccidae whose nymphs show a marked resemblance to those of the Aleurodidae. Thus, Newstead (1910) showed it in *Stictococcus dimorphus* and Mahadihassan (1929) in the lac insect, *Laccifer* (*Tachardia*) *lacca*.

The present work was carried out in the Zoological Laboratory of the Lucknow University during my tenure of a University Research Fellowship.

To Prof. K. N. Bahl I am indebted for his kindly guidance and friendly counsel during the progress of this work. The specimens of *Dialeurodes dissimilis* were obtained from bushes of *Ixora parviflora* (N. O. Rubiaceae), close to the laboratory.

II. Personal Observations

A recently moulted pupa of *Dialeurodes dissimilis* is colourless, but as it grows older, it acquires a bright red pigment and, at the same time, increases in size*. When this process is complete, the red pigment extends over the thorax and a part of the abdomen, and no more increase in size occurs as is shown by a comparison of the size at this stage with that of the pupal exuviae after the eclosion of the imago. Thus, the most suitable time to take pupal measurements, for comparison, is when the pupa has fully acquired the red pigment i.e., when it has attained its maximum size. This precaution is not necessary for the earlier instars because no increase in size occurs during the life of each instar as has been shown also for *Trialeurodes* (*Aleurodes*) *vaporariorum* West. by Haergreaves (1915, p. 330) who says:-

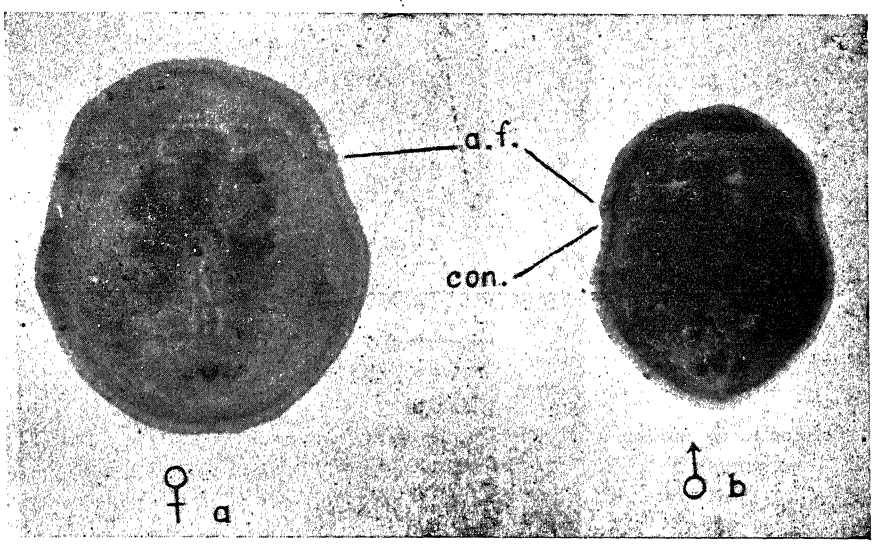

Fig. 1

Fig. 1. Photo-micrographs of glycerine mounts of full-grown pupae of *Dialuerodes dissimilis*. × 51. (a) female (945 μ × 825 μ). (b) male (765 μ × 630 μ). *a.f.*, marginal opening of anterior breathing fold; *con.*, concavity of margin immediately behind *a. f.*

* Throughout this paper, "size" means length and width.

"The first three instars do not grow in length† during their existence, this taking place entirely at the moult; but they grow in thickness (dorso-ventrally). Thus, the length of each of these three instars is constant, and it may, therefore, be used as a criterion of the stage. It varies within 2 μ only. The fourth instar (pupa), however, grows considerably (12μ, in length, and also very much in thickness".

He, however, makes no mention of sexual dimorphism in size among nymphs.

I have made careful measurements of nymphs of the earlier instars with the results given below. Living nymphs, as well as nymphs mounted in glycerine and in canada balsam, were used, without showing any appreciable difference in the results. The length was measured as a line from the median point on the anterior margin to the corresponding point on the posterior margin of a nymph, and the width as the longest horizontal line from margin to margin at right angles to the line of length. In either case, the marginal spines were excluded from the measurements. To ascertain the sex of pupae, I kept some "fully-red" pupae—both large and small—under obsevration with the following result:-

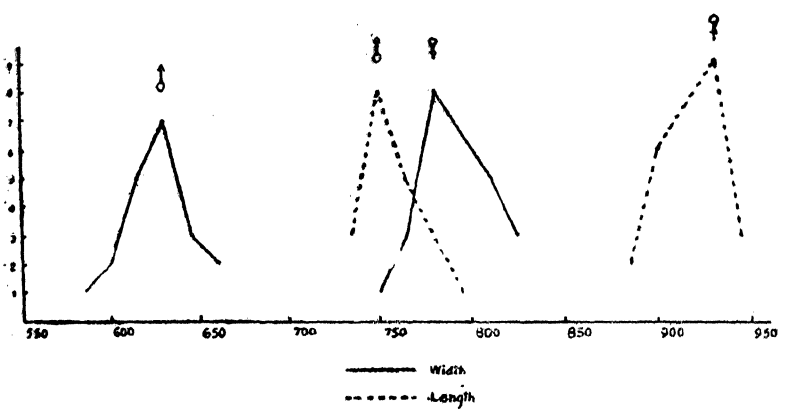

Fig. 2

2Fig. . Graphic representation of the dimensions (length and width in μ) of fully-grown male and female pupae. Note the discontinuous variation which falls into two groups corresponding to the two sexes.

Large pupae ..... from these emerged female imagos.

Small pupae ..... from these emerged male imagos.

From what follows it will be seen that the earlier nymphs also fall into two groups of large and small nymphs, the former presumably being females, the latter males.

† (and, presumably, in breadth also),

Table I. Body size measurements, in microns (μ).

A. M. = Arithmetic Mean.

S. D. = Standard Deviation.

Instar	No. of readings in female nymphs	Female				No. of readings in male nymphs	Male			
		Length		Width			Length		Width	
		A. M.	S. D.	A. M.	S. D.		A. M.	S. D.	A. M.	S. D.
First	20	278	0	188	0	22	239·3	2·4	133·6	3·0
Second	36	435·1	1·8	315·4	1·7	29	373·9	2·2	265·9	12·1
Third	39	620	7·2	492·3	10·2	31	526·9	9·3	409·8	13·7
Fourth(pupa)	20	918·8	20·6	790·5	21·5	20	758·3	14·2	625·8	17·3
Imago	6	847·5	8·2	...	...	6	790	7·7	...	...

III. Discussion and Concluions

It is clear from the measurements (Table I and figures 2 and 3) that from the point of view of size, the nymphs of each instar fall into two well-marked groups without intermediates ; and a comparison with the pupae suggests that, of the nymphs of each instar, the larger ones are females and the smaller ones males.

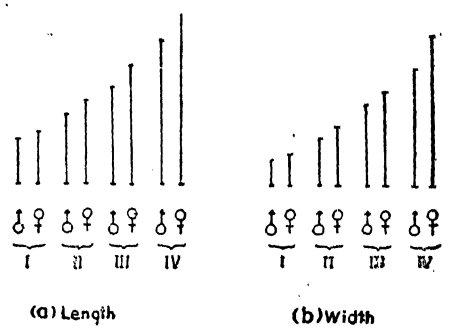

Fig. 3

Fig. 3. Representation of sexual dimorphism among nymphs. (a) in length. (b) in width. Scale: 1 cm.=200μ.

Table II shows that at each successive moult there is a progressive increase of mean difference in size between the male and the female nymphs of each instar (except in the second instar where the difference in width is less than in the first instar). The difference is least in the first instar and greatest in the pupa.

Table III shows that in each instar the ratio length/width is greater in the male than in the female, suggesting that the former is more elongate than the latter; further, in both sexes this ratio decreases with each successive instar i.e., the width always increases more in proportion to the length. The difference in this ratio between male and female nymphs is greatest (0·31) in the first instar; it suddenly drops down to 0·03 in the second instar, and again rises slightly in the fourth instar, thus showing that the elongation of the male nymphs, as compared with the females, is greatest in the first instar, and that they approximate most in the second and third instars. Under the microscope, however, it is not possible, even in the first instar, to distinguish the two sexes by mere shape; in the pupa, as shown below, this is perfectly possible.

Table II. Mean difference in size between female and male nymphs of each instar, in microns (μ).

Instar	In length	In width
First	38·7	54·4
Second	61·2	49·5
Third	93·1	82·5
Fourth	160·5	164·7

Table III. The ratio length/width and its difference in the two sexes of each instar.

Instar	Female	Male	Difference
First	1·48	1·79	0·31
Second	1·38	1·41	0·03
Third	1·26	1·29	0·03
Fourth	1·16	1·21	0·05

Table IV. Increase in size between two consecutive instars, in microns (μ).

Between instars	In length		In width	
	Female	Male	Female	Male
1 and 2	157·1	134·6	127·4	132·3
2 and 3	184·9	153·0	176·9	143·9
3 and 4	298·8	231·4	298·2	216·0

Table V. Ratio of growth, L_m/L_{m-1}, (see page 206) at each moult.

Moult between instars	Length		Width	
	Female	Male	Female	Male
1 and 2	1·57	1·58	1·68	1·99
2 and 3	1·42	1·41	1·56	1·54
3 and 4	1·48	1·44	1·61	1·53

Table IV shows that the mean increase in the size of nymphs with each successive instar is always greater in the female than in the male (except in the width increase between first and second instars which is greater in the male than in the female). The total mean increase of size from the first instar to the full-grown pupa is as follows:—

Female		*Male.*	
Length.	Width.	Length.	Width.
640·8μ	602·5μ	519·0μ	492·2μ

Thus, the total increase in size is greater in the female than in the male by about 122μ in length and about 110μ in width.

Table V illustrates the striking uniformity (within a maximum variation of 0·05, except in the width increase at the first moult) of the ratio of growth (i.e., L_m/L_{m-1}, where L_m represents the length or width in a particular instar and L_{m-1} in the previous instar) at each moult in the two sexes. The growth ratio is greatest at the first moult, drops considerably at the second and again rises slightly at the third (except in the width increase in the male where a slight fall is registered).

We thus get an idea of the way in which the two sexes behave regarding growth.

In the first, second and third instars, it is impossible to distinguish the two sexes by mere shape of the body. In the pupa, however, this is easily possible [*vide* figure 1, (a) and(b)], the following being the differences observed:—

Female	*Male*
1. The portion of the body behind the anterior breathing folds is much expanded sideways when compared with the anterior half, and curves gradually without giving any conical appearance.	1. The portion of the body behind the anterior breathing folds is not much expanded sideways when compared with the anterior half, and curves somewhat abruptly, giving a more or less conical appearance.
2. The concavity of the margin immediately behind the anterior breathing fold is less marked.	2. The concavity of the margin immediately behind the anterior breathing fold is more marked.

Finally, I should not fail to emphasize the importance of the recognition of the existence of sexual dimorphism among the immature stages (particularly the pupa) of the Aleurodidae. In the first, second and third instars, this phenomenon has (so far) only a theoretical interest, since the two sexes can be distinguished only by resort to measurements and statistical tables—a method hardly practicable in identifying specimens. In the fourth instar nymph or pupa, however, the recognition of this fact is extremely important because the classification of the Aleurodidae is based on pupal characters. All the systematic works on the family give only one figure and one set of measurements (usually of a female) of a species, completely ignoring the characteristics of the pupa of the other sex. A mere glance at figure 1 (a) and (b) shows how different the pupae of the two sexes are and it would be easy for systematists to regard them as belonging to different

species, were the existence of sexual dimorphism not taken into account. It is, therefore, imperative that systematic works on this family should contain descriptions of both the male and female pupae.

I have reasons to believe that sexual dimorphism among nymphs occurs not only in *Dialeurodes dissimilis* but in other Aleurodidae also.

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ON SIR SHAH SULAIMAN'S THEORY

By D. R. Sharma

Benares Hindu University

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1. Introduction

The presentation of his new theory,[1] as given by Sir Shah Sulaiman, has been obscure and puzzling at many points, and not free from contradictions. There is no doubt that a more rigorous presentation is necessary for the mathematicians to undertake its study. Consider for example the statement[2] "and although $v'-u=0$ and therefore $v=0$, the ratio,

$$\frac{v}{v'-u}=\frac{1}{1-u^2/D^2}."$$

Again[3] "this corresponds in form with the famous formula assumed by Einstein for the addition of relative velocities" etc. Those who have studied the theory of Relativity know, the limited number of assumptions of the theory, and need not be told that there is no extra assumption made about the addition of velocities. One wonders whether the author of the new theory has appreciated fully the philosophy of Relativity, (vide for example, the section on the transformation formula on page 247, where the author has discovered some fallacies in the Relativistic assumptions).

2. Contradictions and Mis-statements

As regards contradictions one may point out one instance. On page 218 the author rejects the cosmological principle, that all observers should observe the same picture of the universe, and yet is very much satisfied to obtain on page 235 a similar principle from some considerations presented by himself. It is certainly a mis-statement of facts on pages 235-236, that

in Relativity, a nebula must be moving in a direction away from the earth as origin. Reference should be made in this connection to page 13 para 2 of the 'Expanding Universe' (1933) by Eddington, where it is clearly stated "We shall therefore no longer regard the phenomenon as a movement away from our galaxy. It is a general scattering apart having no particular centre of dispersal."

The author of the new theory must make up his mind, whether there should be one universal principle, such as Milne's extended principle and if he incorporates such a principle in the new theory, an earlier theory should not be rejected for having incorporated a similar principle.

3. The law of composition of velocities

D appears later as the velocity of a standard messenger on page 242. If actually an experiment is performed we want to know what D will be. Most of the modern experiments in this connection are optical, and use light as the standard messenger. One does not see any advantage in using quite a new and unknown messenger, whose velocity also is not definitely known. One would be moving against the current of the whole of modern science if one makes and uses an idle prediction as the basis of a new theory on the chance that bigger and better instruments may prove the prediction to be true.

If D is the velocity of the gravitons we expect in the notation of page 243 and in the view of the author's own statement, that the velocity of gravitons is independent of the source, that when $v' = D, v$ should be also D. But

$$\frac{v}{D-u} = \frac{(2D-u)}{2(D-u)}$$

$$\text{or } v = D - \tfrac{1}{2}u \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

on putting $v' = D$ in the formula

$$\frac{v}{v'-u} = \frac{D(D+v'-u)}{(D+v')(D-u)}.$$

on page 245, (1) is a strange result and no explanation of it is given by the author in his new theory.

One cannot understand the result

$$\frac{v}{v'-u} = \frac{D(D+v'-u)}{(D+v')(D-u)} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

for one obvious reason. If v' and u are reversed, we should get $-v$ as the relative velocity. But on changing the signs of v' and u we find, adopting the hypothesis that the messenger starts from A and returns to A after reaching B,

$$\frac{v_1}{-v'+u}=\frac{D(D-v'+u)}{(D-v')(D+u)} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

so that $v_1 \neq -v$, thus the absolute magnitude of what is called the apparent relative velocity (v) changes as the directions of motions of A and B are reversed. This result is quite queer and relativity at least is not responsible for such a result.

A distinction[4] has been made between the true relative velocity and apparent relative velocity ; a distinction unknown to relativity. It is difficult to understand what meaning is to be attached to the true relative velocity when, it cannot be observed by any observer. What an observer will observe will be the apparent relative velocity, and it is the observed results which should form the basis of any new scientific philosophy rather than the results that cannot be observed.

On page 243 in section (2) an experiment is described in which A considers himself at rest. We cannot understand how then the relative velocity of B in the estimate of A becomes $v'-u$. Because $v'-u$ is the true relative velocity and, for any experimental purpose, it is the apparent relative velocity of B that must be taken. Otherwise it becomes an experiment which cannot actually be performed. The apparent relative velocity[5] is $K(v'-u)$ and K depends on the knowledge of u. Hence as

$$K \overset{(6)}{=} \frac{(D-u)\ (D+v')}{(D+u)\ (D-v')} \quad (4)$$

if A considers himself as at rest, $u=0$, and

$$\therefore \quad K = \frac{(D+v')}{(D-v')} \quad (5)$$

Incidentally it may be noticed here that K can vary in magnitude from 0 to ∞. Hence one must know the absolute velocity of the other object to find the apparent relative velocity.

The above conclusions are reached from the considerations of the transformation formula[7] and yet if we go by (2) when $u=0$

$$\frac{\text{The apparent relative velocity, } (v)}{\text{The apparent relative velocity } (v')} = 1 \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

But the other considerations have shown us that the ratio is

$$\frac{D+v'}{D-v'} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

These points are puzzling, and we hope that the author will throw a flood of light on these knotty questions in order to encourage the study of this new theory.

4. Conclusion.

There is one inevitable conclusion that arises from the study of this paper. The success on the formal side of the theory of Relativity has been stupendous and that, if the theory fails in some of its crucial tests, the explanation may be this; not that there is any inherent weakness in the formal aspects of the theory, but that the equations of the general theory of relativity may have to be slightly modified. The relativist will be the first to state that the last word has not yet been said about the general equations of Relativity.

The problem of the world structure is a very wide one and to apply Relativity to it, not to think of the Newtonian theory, has been considered to be a risky extrapolation[8]. To treat such a problem one could proceed either with first principles as is done by Milne, or one could proceed with a strictly logical generalisation of the Relativity theory. One is therefore very sceptical about the success of a new theory in which an orthodox philosophy is strangely wedded to bizarre ideas such as self-acceleration[9].

I should like to express my thanks to Prof. V. V. Narlikar for his kind help and advice.

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2. Sulaiman, S. M. *Ibid*, p. 247
3. Sulaiman, S. M. *Ibid*, p. 246
4. Sulaiman, S. M. *Ibid*, p. 245
5. Sulaiman, S. M. *Ibid*, p. 247
6. Sulaiman, S. M. *Ibid*, p. 248
7. Sulaiman, S. M. *Ibid*, p. 247
8. Tolman, R. C. *'Relativity, Thermodynamics and cosmology'* p. 331, 1934.
9. Sulaiman, S. M. *Ibid*, p. 230.

REPLY OF SIR S. M. SULAIMAN TO THE CRITICISMS OF MR. D. R. SHARMA.

The criticisms are welcome and are dealt with serially :—

1. Introduction.

1. The critic begins by saying "The presentation of the new theory has been obscure and puzzling on many points and not free from contradictions".—It is hoped that obscurities will be removed as more and more chapters are brought out and it is submitted that there is no contradiction.

2. The critic objects to the ratio $v/(v'-u)=1/(1-u^2/D^2)$ when $v=0$. But this is the necessary result of the algebraical substitution $v'=u$ when the double journey method is employed.

3. "This corresponds in form with the famous formula assumed by Einstein for the addition of relative velocities."—The critic apparently objects to the word "assumed" and says that this is not any extra assumption. I believe that this formula might well have been first assumed by Einstein to explain the Michelson and Morley experiment, and possiby working backwards he deduced the hypothesis of the absoluteness of the velocity of light. It matters little whether one or the other is the first assumption.

4. "One wonders whether the author has not appreciated fully the philosophy of Relativity". – I frankly admit that I cannot appreciate the "philosophy of Relativity" because I do not consider its unconvincing postulates to constitute any rational philosophy at all and I maintain that the unreal world is not intelligible to mere three-dimensional human beings. It is really an incomplete representation of gravitational propagation. In the words of Eddington himself "if we are to continue to picture the system in Euclidean space, the properties attributed to it by Relativity are so unusual that they cannot be described without self-contradiction."

5. "The author has discovered some fallacies in the Relativity assumptions". – Numerous anomalies have already been pointed out in my papers. A later chapter will deal more fully with the inherent fallacies in Relativity.

2 "Contradictions and mis-statements."

6. The only supposed contradiction which the critic claims to have discovered is that on page 218 I rejected *the* cosmological principle of Milne and on page 235 I deduced *a* cosmological principle. The critic has not appreciated that my cosmological principle of the constancy of the relation of acceleration to velocity is not identical with Milne's cosmological principle of equivalent observers. I can certainly maintain one and not admit the other.

7. "It is certainly a misstatement of facts on pages 235 to 236 that in Relativity a nebula must be moving in a direction away from the earth as origin". – The objection can be valid only if it has been supposed that I had meant that the nebulae are moving away from the earth only. That I never meant to say that in Relativity the earth is the *only* centre from which nebulae are moving away would be patent from my remark on page 221. "The super-system of galaxies is dispersing as if it were a puff of smoke or as if a gas suddenly released would expand."

8. "The author must make up his mind whether there should be one universal principle such as Milne's extended principle".—As Milne has adopted Einstein's special theory of relativity in its kinematical aspects I have unhesitatingly rejected it.

"The law of composition of velocities".

9. "We want to know what D will be.....One does not see any advantage in using quite a new and unknown messenger whose velocity also is not definitely known".—Apparently the critic has not appreciated that the three formulae obtained by me in chapters 1 and 2 show that D is equal to c. Reference to chapter VI, section 6 para 3 is invited.

10. "When $v' = D$, v should be also D, but strangely this is not so and no explanation is given of it by the author in his theory".—The critic forgets that the formula has been obtained by the method of the messenger's double journey. If $v' = D$ then the messenger would never

overtake the receding body much less return to perform the double journey. In the limiting case when v' approaches D, $v = D - \frac{1}{2}u$ certainly, and this is simple dynamics. It is not claimed that the double journey method is the ideal method, but that if that particular method be adopted the result is as indicated.

11. "If v' and u are reversed we should get v as the relative velocity, but the apparent relative velocity changes.....The result is quite queer." —On the double journey method the relative velocity is not only a function of the difference between two absolute velocities but of the actual absolute velocities themselves. To the order $(v/D)^2$ there is no difference, but for a higher approximation a small difference comes in if the velocities of the receding body and the approaching body be changed. Chapter 7 will throw light on what has been considered 'not quite clear' by the critic.

12. "A distinction has been made between the true relative velocity and apparent relative velocity—a distinction unknown to relativity".—That distinction is between the real relative velocities of two bodies in absolute space and the relative velocity of another body when the observer wrongly considers himself to be at rest.

13. "It is difficult to understand what meaning is to be attached to the relative velocity when it cannot be observed by any observer."—The true relative velocity exists in nature and produces results whether any observer is observing them or not, and these results are real and their cumulative effect can be observed even after the lapse of centuries in the case of heavenly bodies.

14. "We cannot understand how the relative velocity of B in the estimate of A becomes v'-u.—If A be not conscious of his own motion he will regard the other body as moving away from him with a velocity equal to the difference in their velocities.

15. "If A considers himself at rest, $u=0$ and $K = (D + v')/(D-v')$." —u is the absolute velocity of A and by his merely considering himself at rest u will not become zero.

16. "K can vary in magnitude from 0 to ∞".—Only when it were wrongly supposed that even if a body is receding with the velocity of the messenger the latter can overtake it and perform the return journey.

17. The transformation formulae do not give exactly the same ratio as the other formula. Chapter 7 will explain how the relative velocity must vary when the method of measurement is changed.

18. "These points are puzzling and we hope that the author will throw a flood of light on these knotty questions".—It is hoped that chapter 7 will throw such light.

"Conclusion"

19. "The explanation may be that the equations of the general theory of Relativity may have to be slightly modified".—So long as the orbital equation involves $ds=0$ for light as the fundamental postulate, the general Relativity theory is not capable of any substantial modification, and if that postulate is abandoned the theory will collapse. On Newtonian principles, exactly the same orbital equation can be obtained both for matter and light, without that postulate, giving better results.

20. "One should proceed..... as is done by Milne, or proceed with a strictly logical generalisation of the Relativity theory".—Milne's theory which regards the universe as if it were a continuous fluid cannot be true, nor has any logical generalisation of the Relativity theory been yet expounded.

21. The critic offers no criticisms on the recession of the nubulae but merely declares self-acceleration "a bizarre idea". Apparently he would prefer to believe that the nebulæ, though really found to be dispersed in a strictly three-dimensional space are situated on a three-dimensional skin of a four-dimensional continuum, repelled from each other by a cosmic force increasing with the distance between them resulting in a general scattering of the universe. To him a simpler explanation directly deducible from the law of the conservation of momentum (see chapter VI, section 5) is bizarre. No further remaks are necessary.

A NEW MODEL DEMOUNTABLE VACUUM FURNACE.

By M. N. Saha and A. N. Tandon

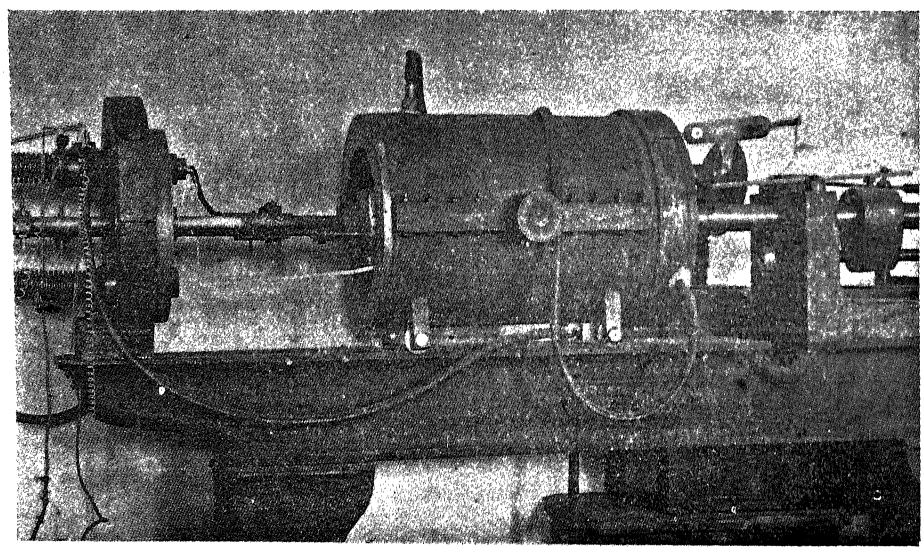
Physics Department, University of Allahabad

Received February 18, 1936

A vacuum graphite furnace suitable for high temperature research has been described in this paper. A special feature of the apparatus is that the parts can be taken out and set again for experimental work in a very short time. Temperatures upto 2500°C can be very quickly attained within a vacuum of 10^{-4} mms. A photograph of the apparatus and four diagrams explaining its action are given.

Introduction

For some time past we have been using in this laboratory a new model vacuum furnace of which the parts are demountable. This has been found to be extremely useful for researches on Thermal Ionisation of elements and salts and other high temperature work. With this apparatus it has been possible to attain temperatures up to 2500°C within a graphite tube very quickly. The special feature of the apparatus is that it can be taken to pieces in no time and set again for a fresh experiment. A photograph of the apparatus showing the important parts is shown below.



Description

The working of the apparatus will be clear from diagrams (1 and 2) which represent its horizontal and vertical sections. The main furnace consists of a water-cooled cylindrical drum C of cast iron and two hollow cast iron plates A and B which close the open ends of the drum when the furnace is working. A, B and C are all vertically mounted on a horizontal lathe bed. The plate A is fixed on one extremity of the lathe bed by the support SS as shown in figures 1 and 2. The drum C is mounted on four small wheels which enable it to slide easily over the lathe bed. The plate B is carried on the axle of a shaft which can be moved by means of a differential screw. When all internal connections and adjustments have been made, the drum C is moved to make contact with A, and B is moved by means of the differential screw and finally

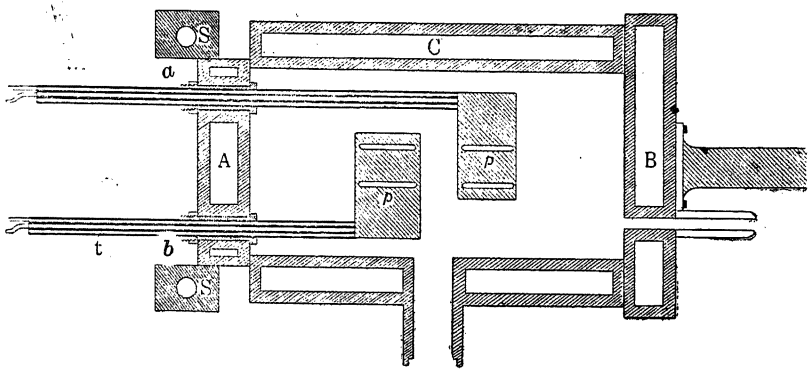


fig. 1

tightened till the contact faces become vacuum tight. In order to ensure better contact between A and C, the support S of the plate A has been so designed that on slightly losening the screws it itself adjusts its face in contact with that of the drum C when the vacuum is started. The apparatus is then ready for use. Although the contact faces between A, B and C are very accurately ground, in practice it is sometimes found necessary to apply a little plasticine round the edges. As all the parts A, B and C are water cooled, the contact faces remain quite cool even when the furance is heated for hours at the highest temperature.

The fixed plate A contains four holes *a*, *b*, *c*, *d* as shown in figures 1 and 2. Through the holes *a* and *b* are inserted two water-cooled annular tubes *t* which are insulated from A by mica. The brass tubes *t* are scooped out from solid brass rods. On the water-cooled end they carry exactly fitting heavy copper collars ending in horizontal copper plates *p* provided with slots as shown in fig 1.

Over the plates p are put Acheson graphite blocks G (fig 3), to receive the furnace tube in the hollow cylindrical space. After the graphite tube is put in position, the upper part of the graphite blocks G are put over it, and the tube is then tightened by means of iron bolts. It is very important that the graphite

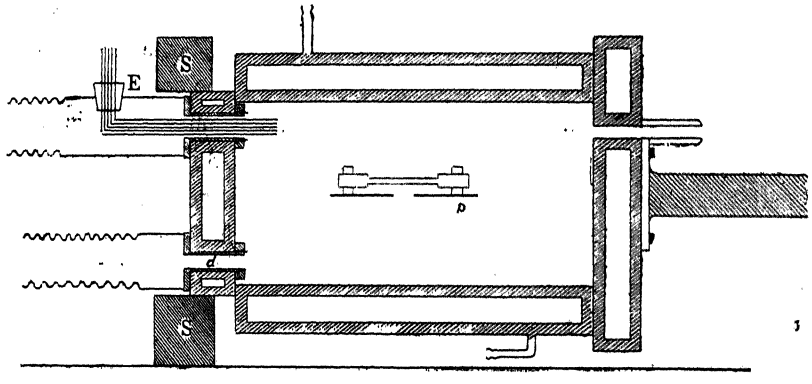


Fig. 2

tube should exactly fit in the blocks. The slightest loose contact between the tube and the graphite blocks causes arcing and makes the temperature of the furnace unsteady. For this reason it becomes necessary sometimes to insert some thin copper foils round the ends of the Acheson graphite tube before putting it between the graphite blocks.

The manner in which the electrodes are attached to the plate A becomes clear from fig. 4 which shows an enlarged drawing of this coupling. A brass tube having threads on one end and a collar K on the other is carefully soldered to the scooped out rod t at the desired distance. Over this is rapped some mica m and is then put inside the hole a of the plate A. The collar is also insulated from the plate A by mica washers m. In order to make perfect vacuum-tight coupling a rubber washer R is put on the other side and the electrode is fixed in position by tightening the nut N. This arrangement is specially advantageous for two reasons, firstly that the electrodes can be taken out whenever required; secondly, the thick copper plates p which are attached to the electrodes can be brought out to the same level by slight adjustments of the nuts N. This precaution is particularly necessary for the fact that if the electrode plates are not in the same level, the furnace tube which is put on them by means of the graphite plugs G, as described above, encounters a mechanical strain which very often breaks it.

Through the holes *c* and *d*, each 2·5 cms. in diameter are connected two four-stage mercury pumps. For our climate (Allahabad) we have found it useful to increase the length of the cast-iron tube which is placed over the conical mouthpiece of the pump. This can be cooled by a freezing mixture. The connection is taken by means of a side tube on the top. The connecting pieces between the pumps and the holes *c* and *d* are Tombac tubings provided with brass end pieces. The coupling between the Tombac tubing and the plate A is done in the same way as that of the electrodes and the vacuum tight contact is obtained by rubber washers. On the pump side the Tombac tube is connected by carefully ground brass cones. With such arrangement the pumps are very quick acting and even with one pump a vacuum of 10^{-4} mms is reached within a short time after starting the pump.

The brass piece of one of the Tombac tubings is bigger in length and has a hole through which passes an ebonite block E (fig. 2) which can carry all the electrical connections inside the furnace.

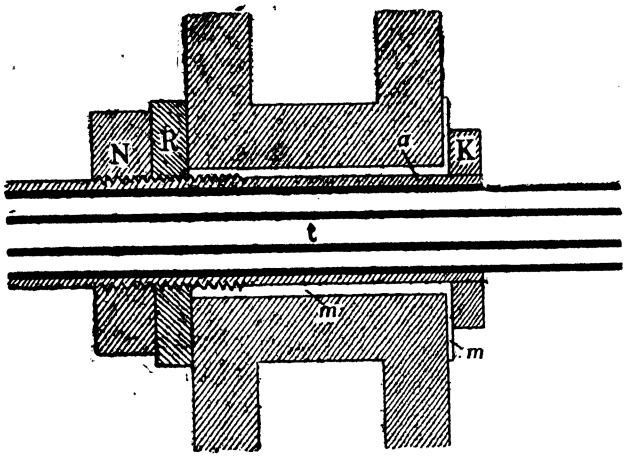


fig 4

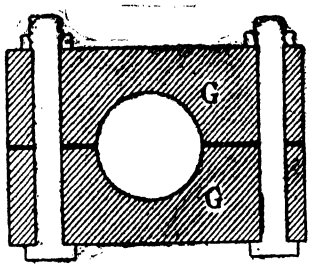


fig 3

The water-cooled sliding drum C contains a side-tube through which the inside of the furnace can be inspected. This also enables the temperature of the furnace to be measured from outside by means of a disappearing-filament type of pyrometer. A thermo-couple can be inserted through this hole whenever required.

The movable plate B has a single hole through which a discharge tube can be inserted for giving an indication of the degree of vacuum,

The electrodes are connected by thick copper leads to a low-tension transformer (capacity 12 K. W.). A current of the order of 1000 amperes is allowed to flow through the graphite tube to raise it to a high temperature. The transformer has got four other ranges for giving less temperature.

We wish to express our sincere indebtedness to the Royal Society of London for giving us a grant of £ 150 which has enabled us to construct the furnace and to buy its accessories. Our thanks are also due to Messers Allahabad Foundry for the casting of the plates and the water-cooled drum.

A NEW SPECIES OF THE GENUS *HARMOTREMA* NICOLL, 1914 WITH A DISCUSSION ON THE SYSTEMATIC POSITION OF THE GENUS AND CLASSIFICATION OF THE FAMILY HARMOSTOMIDAE ODHNER, 1912.

By H. R. Mehra

Zoology Department, University of Allahabad

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SUMMARY

A new species of the genus *Harmotrema* Nicoll from the small intestine of *Gavialis gangeticus* is described. This species is remarkable in combining in itself some of the characters of the two already known species of the genus, *H. infecundum* Nicoll, 1914 and *H. laticaudae* Yamaguti, 1933 which are parasitic in water snakes. The systematic position of the genus is discussed and it is shown that *Harmotrema* is closely related to *Helicotrema, Liolope* and *Moreauia*. The subfamily Liolopinae occupies an intermediate position between the subfamilies Harmostominae and Harmotrematinae. The historical account of the family is given and its classification discussed. The families Leucochloridiidae Dollfus, Liolopidae Dollfus and Hasstilesiidae Hall are reduced to the rank of subfamilies. A classification of the family with keys to the subfamilies and genera is given.

Introduction

The little known genus *Harmotrema* Nicoll, 1914 hitherto includes only two species, *H. infecundum* Nicoll, 1914 and *H. laticaudae* Yamaguti, 1933 both from the small intestine of water snakes, *Grayia smithii* and *Laticauda laticaudata* respectively. In this paper is described a third species obtained from a Crocodilian host, the common Indian Gharial, *Gavialis gangeticus*.

The systematic position of the genus *Harmotrema* is not without interest. This genus is more closely related to *Helicotrema* Odhner, 1912 than to *Liolope* Cohn, 1902. It also bears a fairly close resemblance to the aberrant genus *Moreauia* Johnston, 1915. The close affinities of

Harmotrema with *Liolope* and *Helicotrema* led Dollfus (1931) to include them in the subfamily Liolopinae Cohn, 1902. Later, Dollfus (1934) created the family Liolopidae and divided it into two subfamilies Liolopinae Cohn and Moreauiinae Johnston, 1915, which were previously included in the family Harmostomidae. This brings us to the discussion of the classification of the latter family. As the subfamily Liolopinae occupies an intermediate position between the subfamily Harmotrematinae Yamaguti, 1933 and the subfamily Harmostominae Braun, 1900, it is considered necessary to drop the family Liolopidae Dollfus, 1934 and keep the family Harmostomidae Odhner, 1912 in tact as it has been so far constituted. The families Leucochloridiidae Dollfus, 1934 and Hasstilesiidae Hall, 1916 are also reduced to the rank of subfamilies. It is not desirable to multiply the number of families on the basis of relatively minute differences.

Harmotrema nicollii sp.n.

Host: Crocodilian, *Gavialis gangeticus.*

Frequency: Present in nearly every host.

Position: Small intestine.

Locality: Allahabad, U. P. (India).

Numerous specimens were obtained from the small intestine of the common Indian Gharial, *Gavialis gangeticus,* one of the Crocodilia commonly available in the Ganges at Allahabad. Nearly every host was found infected with these parasites, which were so deeply attached to the gut wall that they took sufficiently long time i. e., about an hour or more to come out, when the latter was kept open in normal salt solution. Sometimes the specimens were collected by scraping along the walls. All the measurements are in millimetres and taken from entire mounts of distomes slightly pressed under a coverglass.

The body is very small, narrow and elongated, conical or pear-shaped, bluntly pointed at the anterior end, broad and rounded at the posterior end, measuring 1·6-2·58 in length and 0·6-0·68 in maximum breadth which lies behind the middle in the region of the cirrus sac and gonads. The cuticle is entirely devoid of spines. The anterior part of the body is extensile and can be produced into a long narrow neck; its parenchyma is filled with deeply staining cells of glandular nature, which are clearly seen on account of the absence of the genital organs here.

The oral sucker is subterminal and spherical or oval, measuring 0·085-0·1 in length and 0·068-0·085 in breadth. The ventral sucker is slightly larger than the oral sucker and spherical, measuring 0·12-0·15 in diameter. It is situated at about one third body length from the anterior end or just in front of the middle, depending upon the state of extension of the worm. The prepharynx is absent. The pharynx is spherical and 0·04-0·068 in diameter. The oesophagus is short and has about the same length as the pharynx, i. e., 0·05-0·068. The intestinal caeca are simple, commencing 0·22-0·24 distance behind the anterior end and terminating near the hinder end immediately behind the posterior testis. In front of the ventral sucker the caeca are situated nearer the median line than the body wall, but behind it they diverge outwards, so that in the hinder half of the body they lie nearer the body wall outside the cirrus sac and the gonads, till they turn inwards near the posterior margin of the posterior testis to terminate on each side of the excretory opening in front of the hinder end. The excretory pore is subterminal, situated on the dorsal surface a little in front of the posterior end of the body. It leads into a very short median vessel which bifurcates immediately behind the caudal ends of the caeca into two main branches. The latter soon divide each into two large trunks, which run parallel to one another on either side of their respective caecum. The outer trunk extends as far forwards as the middle of the pharynx, and the inner one ends a little behind, i. e., at the intestinal bifurcation, close behind which the two trunks of each side are joined by a transverse connection. The two inner trunks are also connected by a transverse vessel at a little distance in front of the ventral sucker.

The reproductive organs except the anterior part of the vitellaria lie in the posterior half of the body. The two testes with the ovary and the shell gland complex between them are crowded together between the caeca in the hinder one third to one fourth part of the body length, which we prefer to call the genital field or genital gland field after Braun (1900). The anterior testis, elliptical or ovoid in shape, lies median immediately behind the metraterm and much behind the middle of the body, measuring 0·187 in length and 0·3 in maximum breadth. The posterior testis has also a somewhat ovoid form and lies median closely in front of the hinder end, at about 0·1 distance from it, measuring 0·22 in length and 0·27 in maximum breadth. The large cirrus sac with thin parenchymatous walls is

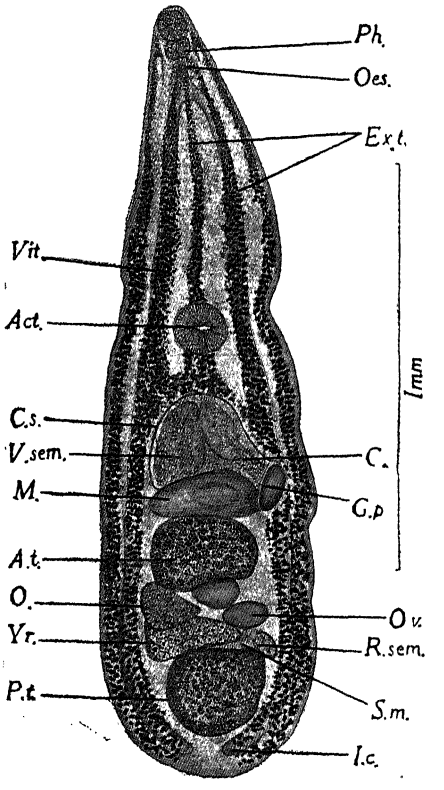


Fig. 1.

Fig. 1. Ventral view of *Harmotrema nicollii* sp. n. *Act.*: Acetabulum; *A.t.*: Anterior testis; *C.*: Cirrus: *C.s.*: Cirrus sac; *Ex.t.*: Excretory trunks; *G.p.*: Genital pore; *I.c.*: Intestinal caecum; *M.*: Metraterm: *O.*: Ovary; *Oes.*: Oesophagus; *Ov.*; Ovum; *Ph* : Pharynx: *P.t.*; Posterior testis; *R. sem.*: Receptaculum seminis; *S.m*: Shell gland mass ; *V.sem.*: Vesicula seminalis; *Vit.*: Vitellaria; *Y. r.*: Yolk reservoir.

situated transversely in the median line between the caeca, at 0·12 – 0·136 distance behind the ventral sucker and 0·73 distance in front of the hinder end, measuring 0·34 – 0·42 in length which lies across the body and 0·13 – 0·22 in maximum breadth at the base, which lies a little to the right side close to the right intestinal caecum. It is strongly bent or crescent-shaped with the concavity on its posterior margin, and opens by a small tubular distal part at the wide genital aperture, which is post-equatorial situated ventrally to the left side close to the left intestinal caecum, at 0·187 – 0·3 distance behind the ventral sucker (in much flattened specimens 0·4 behind it)

and 0·68 – 0·73 in front of the hinder end. The vesicula seminalis is large and almost fills the swollen part of the cirrus sac ; it is bipartite, consisting of a large oval proximal and small elongated distal parts. The pars prostatica is surrounded by the well developed prostate gland cells, which fill up all the available space within the cirrus sac. The cirrus, 0·14 – 0·21 long and 0·08 – 0·09 broad when protruded, is club-shaped with a broad rounded terminal end, and beset with prominent dark brown and sharply pointed spines of 0·007 – 0·014 length and 0·0034 breadth at the base.

The ovary, 0·13 – 0·15 by 0·12 – 0·15 in size and roughly triangular or conical in shape, is much smaller than the testes, and lies immediately behind the anterior testis to the right side with its pointed end near the median line and the broad outer end pressed against the right intestinal caecum. It is composed of large egg cells and is separated from the posterior testis by the yolk reservoir, which appears as a solid mass of vitelline cells, situated mostly to the right side. The receptaculum seminis is 0·07 – 0·13 by 0·034 – 0·064 in size, and is situated to the left side in front of the yolk reservoir and behind the anterior testis. The uterus is extremely short and thrown into two small coils, one situated to the left side of the ovary and the other in front of it between the anterior testis and the metraterm, containing only a few large ova. The metraterm, 0·3-0·36 in length and 0·1 in maximum breadth, is a straight spacious tube with cuticular walls, occupying almost entirely the transverse intercaecal space between the cirrus sac and the anterior testis. The ova, 1 – 10 in number, are large and oval with a thick shell of yellow colour and measure 0·119 – 0·126 by 0·075 – 0·085 in size.

The vitellaria are extensively developed, beginning much in front of the ventral sucker, i.e., a little behind the intestinal bifurcation and terminating at the posterior end of the body on each side of the excretory opening. They are composed of small follicles which are situated laterally behind the cirrus sac, outside and overlapping the caeca both dorsally and ventrally ; but in front of the cirrus sac those of the two sides cross the caeca and become continuous to form a large mass, which is more or less arranged in four longitudinal rows outside and overlapping the excretory trunks. The vitellaria, however, do not extend inwards behind the posterior testis to become united with one another as in *Harmotrema laticaudae* Yamaguti, nor are the follicles arranged in irregular patches as in the latter species. The large vitelline reservoir lies behind the ovary partly overlapping its posterior margin, and mostly to the right side.

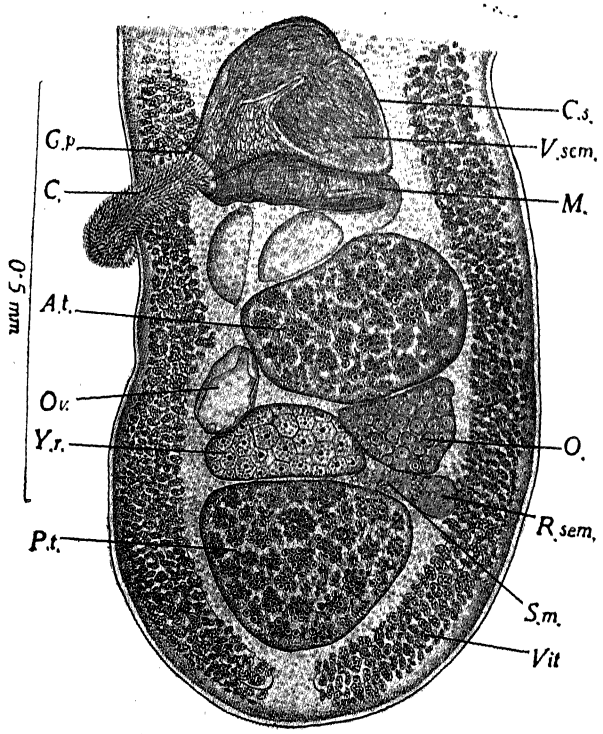


Fig. 2

Fig. 2. Much magnified hinder region of *H.nicollii* sp. n. with protruded cirrus. Dorsal view.

Remarks:—The new species resembles *Harmotrema infecundum* Nicoll, 1914 in the small size of its body, post-equatorial position of the genital pore, relatively smaller number of its ova and the vitellaria extending in front of the acetabular zone; but it differs from it in having entire, and not lobed gonads, in the median position of the anterior testis, a little more anterior position of its genital pore, in the shape and position of the cirrus sac, on account of the armed cirrus, presence of the receptaculum seminis, smaller size of the ova and the crocodilian host. Though it resembles *Harmotrema laticaudae* Yamaguti, 1933 on account of the median position of the anterior testis, armed character of the cirrus, similarity in the excretory system and almost equal size of the ova, it differs remarkably in many features, such as the small size of the body, post-equatorial position of the genital pore (pre-equatorial in *H. laticaudae)*, the posterior testis being situated just in front of the

hinder end, presence of the receptaculum seminis, the vitellaria beginning much in front of the acetabular zone and the vitelline follicles being continuous and not aggregated in irregular patches, smaller number of the ova and the host. *Harmotrema nicollii* n. sp. is, therefore, remarkable in combining in itself some of the characters of the two hitherto known species of the genus, and further on account of its being parasitic in a crocodilian host and not in water snakes, from which the other two species have been obtained. The new species is named after Dr. W. Nicoll, who founded the genus.

Table giving the diagnostic characters of the species of the genus *Harmotrema*.

	H. infecundum Nicoll.	*H. laticaudæ* Yamaguti	New spec.
Body size.	2·0 × 0·6.	5·7-6·9 × 1·0-1·2.	1·6-2·58. × 0·6-0·68.
Cuticle.	Unarmed.	Unarmed.	Unarmed.
Oral sucker	0·13 diameter	0·075-0·1 × 0·11-0·13	0·085-0·1 × 0·068-0·085
Ventral sucker	0·8 from anterior end; 0·08 × 0·1	0·81-1·1 from anterior end; 0·11-0·13 × 0·15-0·175	At about one third body or just in front of middle
Prepharynx	Absent.	Absent.	Absent.
Pharynx	0·06 × 0·04.	0·12 diameter.	0·04-0·068 diameter
Oesophagus	About the same length as pharynx.	0·035-0·08 long.	About the same length as pharynx.
Excretory system	Not described.	Characteristic.	Similar to that of *H. laticaudæ*
Genital pore	Almost midway between ventral sucker and posterior end.	Pre-equatorial; 2·09-2·15 from anterior end.	Post-equatorial 0·187-0·3 from ventral sucker 0·68-0·73 in front of hinder end.

Table giving the diagnostic characters of the species of the genus *Harmotrema*

Testes	Irregularly lobed.	Entire.	Entire.
Position of anterior testis	To right side, behind genital pore.	Median, at middle of body.	Median, much behind middle of body.
Position of posterior testis	Separated from posterior end by space of its own diameter.	Seperated from posterior end by space of more than twice its diameter.	Just in front of hinder end,
Cirrus sac	Sinuous, proximal end against right cæcum.	Obliquely across body; 0·8 × 0.43.	Transversely across body; 0·34-0·42 × 0·13-0·22.
Cirrus	Unarmed ?	Club-shaped, armed, 0·44 × 0·15.	Club-shaped, armed, 0·14-0·21 × 0·08-0·09.
Ovary	Iregularly lobed	Not lobed, transversely oval, 0·16-0·25 × 0·23-0·31	Conical, 0·13-·15 × 0·12-0·15
Receptaculum seminis	Absent.	Absent.	Present
Metraterm	Not mentioned.	Retort-shaped, in contact with posterosinistral margin of cirrus sac, 0·44 × 0·21.	Straight, transversely across body, between cirrus sac and ant. testis 0·3-0·36 × 0·1.
Anterior limit of Vitellaria.	Midway between intestinal bifurcation and acetabulum	Acetabular zone	A little behind intestinal bifurcation.
Number and size of ova.	2; 0·15-0·18 × 0·08-0·11.	20 or more; 0·123-0·129 × 0·075-0·078	1-10; 0·119-0·126 × 0·075-0·085.
Host.	Smith's water snake *Gerarchyia symthii*.	Water snake *Laticauda laticaudata*.	Crocodilian *Gavialis gangeticus*.

Specific diagnosis of Harmotrema nicollii n. sp.

Harmotrema Nicoll, 1914. Body minute 1·6 – 2· 58 × 0· 6 – 0· 68; cuticle without spines. Oral sucker 0·085 – 0·1 × 0.068 – 0·085. Ventral sucker 0·12 – 0·15 in diameter, at about one third body from anterior end or just in front of middle. Prepharynx absent; pharynx 0·04 – 0·068 in diameter; oesophagus 0·05 – 0·068; intestinal caeca nearer median line in front of ventral sucker and nearer body wall in hinder half, turning inwards at their termination. Anterior testis elliptical or ovoid, median immediately behind metraterm and much behind middle of body, 0·187 × 0·3. Posterior testis ovoid, median, closely in front of hinder end, 0·22 × 0·27. Cirrus sac median, transversely across body a little behind ventral sucker, crescent-shaped, 0·48 × 0·12-0·22. Vesicula seminalis large. Cirrus armed, club-shaped, 0·14 – 0·21 × 0·08 – 0·09. Genital pore wide, post-equatorial, sinistral. Ovary conical, dextral, behind anterior testis, 0·13 – 0·15 × 0·12 – 0·15. Receptaculum seminis 0·07 – 0·13 × 0·034 – 0·064, to left side in front of yolk reservoir and behind anterior testis. Uterus extremely short; metraterm straight, spacious, transversely across body between cirrus sac and anterior testis, 0·3 - 0·36 × 0; 1. Vitellaria from a little behind intestinal bifurcation to posterior end meeting in front of ventral sucker; vitelline follicles arranged in pre-acetabular region in four longitudinal rows. Ova 1–10 in number, operculate, oval with thick shell, 0·119–0·126 × 0·075–0·085.

Host: Crocodilian—*Gavialis gangeticus.*

Discussion on the Systematic Position of the Genus *Harmotrema*

Nicoll created this genus in 1914 with *Harmotrema infecundum* as the type species and assigned it to the family Clinostomidae Lühe, 1901. Witenberg (1925), though he included it in the Clinostomidae considered it to occupy an intermediate position between this family and the Harmostomidae Odhner, 1912. Travassos (1929) placed it definitely in the Hamostomidae, to which in his opinion it shows greater affinity. Dollfus (1931), while including the families Clinostomidae and Neprocephalidae Dollfus, 1931 in the superfamily Clinostomatoidea, removed the genus *Harmotrema* from the Clinostomidae and Brachylaemidae Joyeux and Foley, 1930 (syn. Harmostomidae) to the subfamily Liolopinae Cohn which in 1934 he raised

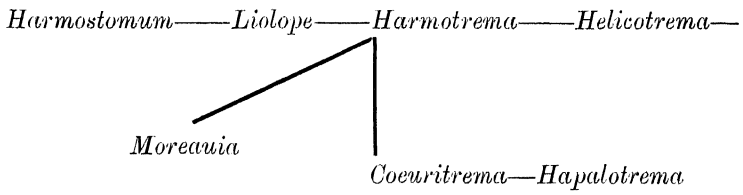
to the rank of a family, dividing it into the two subfamilies, Liolopinae and Moreauiinae S. J. Johnston, 1915. To the former he assigned the genera *Liolope* Cohn, *Harmotrema* and also provisionally *Helicotrema* Odhner. Yamaguti (1933) described a second species, *Harmotrema laticaudae*. He thinks that as the genus *Harmotrema* does not fit well in the Clinostomidae, it possibly represents a new family, though for the present he creates a new subfamily Harmotrematinae for it under the Clinostomidae. Dollfus (1934), however, does not recognise this subfamily, considering it to be synonymous with the subfamily Liolopinae of his new family Liolopidae.

We follow Travassos in including *Harmotrema* in the family Harmostomidae, to which it obviously belongs. Though it shows unmistakable affinities with *Helicotrema* Odhner and *Liolope* Cohn, we do not agree with Dollfus in assigning it to the Liolopinae or his family Liolopidae, in which he also includes the subfamily Moreauiinae Johnston. In *Liolope* the large vesicula seminalis lies in front of the anterior testis outside the small cirrus sac, a condition reverse to that in *Harmotrema*, in which the cirrus sac is large and encloses a large vesicula seminalis, well developed pars prostatica and cirrus. The pars prostatica is reported to be absent in *Liolope*. Besides the uterus in the latter genus which is much larger and contains a large number of thin-shelled ova approaches that of the Harmostominae rather than that of the Harmotrematinae, in which it is short, containing a few large thick-shelled ova. These differences justify the retention of the subfamily Harmotrematinae, in which we also include the genus *Helicotrema* as it is more closely related to *Harmotrema* than to *Liolope* on account of the presence of a large cirrus sac with the vesicula seminalis inside it, and the short uterus with a small number of large thick-shelled ova.

The aberrant genus *Moreauia* Johnston, though much modified on account of a profound transformation in shape and the consequent rearrangement of the relative position of some of the organs, no doubt bears a fairly close resemblance to *Harmotrema* in the sinistral position of the genital opening, which in *Moreauia* has become shifted to the extreme lateral margin, and in the presence of a large cirrus sac enclosing well developed vesicula seminalis, pars prostatica and cirrus armed with prominent spines. Besides, the vitellaria are also extensively developed in both these genera, occupying all the available space. In the extent of the uterus and the large number of ova, however, *Moreauia* resembles *Liolope* rather than *Harmotrema*. But it has such distinctive features, as Johnston has pointed out, that it must be included

in a separate subfamily, the Moreauiinae Johnston, which is closely related to the Harmotrematinae and Liolopinae.

The condition of the uterus, cirrus sac and vesicula seminalis visualizes that the Liolopinae should occupy an intermediate position between the Harmostominae and the Harmotrematinae, and we are, therefore, obliged to drop the family Liolopidae Dollfus, 1934 and keep the family Harmostomidae in tact, as it has been so far constituted. We may indicate the relationships of the genera of these subfamilies in the following natural series :—



Moreauia stands apart as an isolated branch, which arose between *Liolope* and *Harmotrema* but nearer the latter genus. The blood flukes of the subfamily Hapalotreminae Stunkard (Family Spirorchidae Stunkard) represent another well known natural branch which arose between *Liolope* and *Harmotrema*. It is interesting to note that the evolution of all these genera is closely bound up with the evolution of their hosts. The genus *Moreauia*, aberrant as it is, became established in *Ornithorhynchus*, one of the Prototheria, which as it is well known arose from some primitive reptile. The genus *Harmostomum* and its closely related genera, which constitute the subfamily Harmostominae, became established in birds and mammals through their reptilian ancestors of which we know nothing ; while *Harmotrema* and *Helicotrema* parasitic in reptiles and *Liolope* parasitic in Amphibian host have maintained the primitive habitat in their respective hosts.

Discussion on the Classification of the Family Harmostomidae.

Though the family Harmostomidae has recently received much attention and has been subject to much revision, there exists profound difference of opinion about its classification. Braun (1899) proposed the genus *Harmostomum* for *Distomum leptostomum* Ollson, *Distomum spinulosum* Hofmann and D. *opisthotrias* Lutz with the first as the type species. Later in 1899 Looss announced his genus *Heterolope* and his subfamily Heterolopinae, including the genera *Heterolope* Looss, *Harmostomum* Braun and *Dolichosomum* Looss, 1899 (syn. *Ityogonimus* Lühe, 1899). He also combined the genera *Leucochloridium*

Carus, 1835 (*Urogonimus* Monticelli, 1888) and *Urotocus* Looss 1899 into the subfamily Urogoniminae on the basis of the terminal position of the genital pore in these genera. Braun in 1900, agreeing with Looss on the principle underlying this scheme, pointed out the priority of the name *Harmostomum* and Harmostominae to *Heterolope* and Heterolopinae. In 1902 he united with *Harmostomum* and *Ityogonimus* his new genera *Glaphyrostomum* Braun, 1901 and *Scaphiostomum* Braun, 1901 on account of the similar arrangement of the gonads. Pratt (1902) included in the Urogoniminae in addition to the two genera by Looss, *Urotrema* Braun, 1900 and *Urorygma* Braun, 1901.

Odhner (1912) created the family Harmostomidae and divided it into the subfamilies Harmostominae Braun and Liolopine Cohn, giving the diagnosis. In the Harmostominae were included the genera *Harmostomum* Braun, *Ityogonimus* Lühe, *Urotocus* Looss, *Urogonimus* Montic. (*Leucochlorhdium*), *Glaphyrostomum* Braun and *Scaphiostomum* Braun on the basis that they form a graded series ; while in the subfamily Liolopinae he included the genera *Liolope* Cohn, 1902, *Helicotrema* Odhner, 1912 and *Hapalotrema* Looss, 1899. It is well known that the last named genus was removed from the Harmostomidae by Ward, and now belongs to the family Spirorchidae Stunkard, 1921. Hall (1916) established for *Distoma tricolor* Stiles and Hassal, 1894, the new genus *Hasstilesia*, the subfamily Hasstilesiinae and the family Hasstilesiidae with diagnosis. Viana (1924) in his tentative catalogue of the Trematodes of Brazil recognised under the Harmostomidae three subfamilies, the Harmostominae Braun, 1899, Leucochloridiinae Poche, 1907 and Liolopinae Cohn, 1902. He included *Urotrema* Braun in the Harmostominae and *Urorygma* Braun in the Leucochloridiinae.

Witenberg (1925) divided the Harmostominae into tribes, *Ithyogonimea*, *Harmostomea*, *Urotocea* and *Leucochloridiea*, each tribe into genera and the genus *Harmostomum* into the subgenera *Harmostomum* and *Postharmostomum*. He also united the families Harmostomidae and Clinostomidae into the super family Clinostomidea on account of the similarity in the position and structure of the genital organs. Poche (1925) recognised the family Hasstilesiidae Hall, 1916 for the genus *Hasstelesia* Hall, and included 12 genera in the Harmostomidae, removing *Urotrema* Braun and *Urorygma*, which possibly on account of their uncertain position, were not included by Odhner in this family. For *Urotrema* Braun, Poche created the new family Urotrematidae distinguishing it from the Harmostomidae. Werby (1928) accepts the classification of the Harmostomidae into tribes and genera as laid down by

Witenberg. She agrees with Odhner that the genera *Harmostomum*, *Ityogonimus*, *Leucochloridium* and *Urotocus*, which form an unbroken series on the basis of morphology should constitute the Harmostominae, contrary to Looss who separated them into two subfamilies, Harmostominae and Urogoniminae.

Travassos (1929) gives an illustrated sketch of the family. He is in agreement with Poche that the genera *Urotrema* and *Urorygma* do not belong to it. He, however, recognises three subfamilies, Harmostominae in which he includes in addition to the six genera assigned by Odhner, *Harmotrema* Nicoll and *Hasstilesia* Hall, Liolopinae for *Liolope* Cohn and *Helicometra* Odhner, and Moreauiinae Johnston for *Moreauia* Johnston. Sinitsin (1931) gives a classification of the Harmostomidae in the light of new facts from their morphology and life-history as studied by him, adding to the diagnosis of the family the habitat and the characteristic features of the cercariae, adolescariae and parthenitae. He divides it into two subfamilies, Harmostominae and Leucochloridiinae, subdividing the former into the tribes *Entosiphonea* and *Ectosiphonea* mainly on the basis of the intracaecal or extracaecal position of the siphons of the excretory bladder. In the tribe *Entosiphonea* are included the genera *Harmostomum*, *Entosiphonus* Sinitsin 1931, *Postharmostomum* Witenberg, 1925, *Glaphyrostomum*, *Hasstilesia* and *Urotocus*, and in the tribe *Ectosiphonea* the genera *Ectosiphonus* Sinitsin, 1931. *Scaphiostomum*, *Ityogonimus* and *Panopistus* Sinitsin. In our opinion it is premature to accept these tribes and the characters on which they are based. Dollfus (1931) as mentioned before removed the genus *Harmotrema* from the Brachylaemidae (syn. Harmostomidae) to the subfamily Liolopinae, which in 1934 he raises to the rank of a family, subdividing it into the subfamilies Liolopinae and Moreauiinae. He also creates in the same year the family Leucochloridiidae for the genera *Leucochloridium*, *Urotocus* and *Urorygma*. The Brachylaemidae then after the separation of these genera, he divides into two subfamilies, Brachylaeminae (syn. Harmostominae) and Hasstilesiinae.

We drop the families Leucochloridiidae Dollfus, Liolopidae Dollfus and Hasstilesiidae Hall and maintain that the genera belonging to them are so interrelated and form such a graded series on the basis of their morphology and life-history as far as known at present, and in this we are supported by such authorities as Odhner, Witenberg, Werby, Travassos and Sinitsin, that it would be subversive of the whole object of natural classification to separate them in different families. It has been already

discussed that the subfamily Liolopinae stands intermediate between the subfamilies Harmostominae and Harmotrematinae, the family Liolopidae is, therefore, untenable. There should be no question about the untenability of the family Leucochloridiidae in view of the recent work on its life-history by Sinitsin, which throws much light on its close affinities with the Harmostomidae. In both the eggs hatch only after they are eaten by snails, and there is no free living miracidium, the parthenitae develop in Pulmonata and produce comparatively a small number of cercariae. The parthenitae are simple or branched in the Harmostominae, branched in the Leucochloridiinae. The cercariae of both are without a natatory tail, stylet, stylet glands and cystogenous cells. From the point of view o morphology, their close relationships have been emphasised by most of the previous workers on the group. The genus *Hasstilesia* is so closely related to the Harmostominae that it is futile to make it the representative of a separate family. Travassos and Sinitsin go so far as to include it in the subfamily Harmostominae; the latter author includes it with *Harmostomum* in his tribe Entosiphonea. A glance at the excellent figures representing the basal plan of structure of the genera of the Harmostomidae as provided by Travassos (1929) will enable one to realise the correctness of the view about dropping the above mentioned families. At the same time it must be admitted that it is necessary to divide the Harmostomidae into subfamilies on the basis of such deep-seated characters as would leave no doubt about the affinities of the genera belonging to them. That some of the characters would overlap more than one subfamily is beyond question, as they are indicative of their inter-relationships. As an example it may be mentioned that the genus *Urotocus*, which stands intermediate between the subfamilies Harmostominae and Leucochloridiidiinae, possesses certain characters of both the subfamilies.

The characters which may be considered as distinguishing the subfamilies are as follows:—

(1) Shape of body: Elongated, tongue-shaped, or thread-shaped, rarely broad and oval in the Harmostominae (*Harmostomum*, *Entosiphonus*, *Glaphyrostomum*, *Ityogonimus*, *Scaphiostomum*, broad and somewhat oval in *Ectosiphonus*); elongated, tongue-shaped or oval in the Leucochloridiidiinae (*Urotocus*, *Urorygma*, *Leucochloridium*, *Panopistus*); short, broad and oval in the Hasstilesiinae (*Hasstilesia*); elongated and flat, sometimes with a groove on ventral surface in the Liolopinae (*Liolope*) and Harmotre-

matinae (*Harmotrema* and *Helicotrema*); much flattened and broadened out, rectangular in shape with the long axis representing the breadth and the short axis the length of the worm in the Moreauiinae (Moreauia).

(2) Position of the genital pore: Median or submedian a little in front of hinder end in the region of testes, or a little more forwards, but much behind ventral sucker in the Harmostominae; submedian i. e., slightly dextral, between testes, about half way between ventral sucker and hinder end in the Hasstilesiinae; terminal or subterminal in the Leucochloridididiinae; much sinistral in front of anterior testis, half way between ventral sucker and hinder end or further in front, a little behind ventral sucker in the Liolopinae and Harmotrematinae; in a depression in the middle of left lateral border in the Moreauiinae.

(3) Vesicula seminalis; Small outside cirrus sac in the Harmostominae, Hasstilesiinae and Leucochloridididiinae; large outside cirrus sac in the Liolopinae; large inside cirrus sac in the Harmotrematinae and Moreauiinae.

(4) Uterus: Large with numerous small ova in the Harmostominae, Hasstilesiinae and Leucochloridididiinae; moderately developed with less numerous large thin-shelled ova in the Liolopinae and Moreauiinae: very short with a restricted number of large thick-shelled ova in the Harmotrematinae.

(5) Vitellaria: Lateral and stripe like extending to anterior testis or ovary in the Harmostominae; to hinder end of ovary or end of body in the Leucochloridididiinae; somewhat massive and lateral in anterior half of body in the Hasstilesiinae; lateral and extensively developed meeting behind or both behind and in front of testes in the Liolopinae and Harmotrematinae; very extensively developed filling up the space between intestinal caeca and various borders of the characteristic rectangular body except around suckers and the region near genital opening in the Moreauiinae.

From the above it follows that in the present state of our knowledge the Harmostomidae should be divided into the following six subfamilies:—

1. Harmostominae Braun, 1899 (syn. Heterolopinae Looss, 1899)
2. Hasstilesiinae Hall, 1916.
3. Leucochloridididiinae Poche, 1907 (syn. Urogoniminae Looss, 1899.)

4. Liolopinae Cohn, 1902.
5. Harmotrematinae Yamaguti, 1933.
6. Moreauiinae Johnston, 1915.

Family Hyrmostomidae Odhner, 1912

Synonym.—Brachylaemidae Joyeux and Foley, 1930.

Family diagnosis.—Distomes of different body forms. Cuticle with or without spines. Prepharynx present or absent; pharynx present; oesophagus small or absent; intestinal caeca terminating near hinder end. Excretory opening terminal or subterminal and dorsal; excretory bladder with a very short and narrow median stem and two long tubular cornua or siphons extending inside or outside caeca to the level of oral sucker (in *Harmotrema* the short median stem divides into four longitudinal trunks of nearly equal length joined with one another by two transverse connectives). Genital opening always behind ventral sucker, usually ventral sometime dorsal, median or submedian in hinder part of body (Harmostominae), submedian about half way between ventral sucker and hinder end (Hasstilesiinae), subterminal or terminal at hinder end (Leucochlorididiinae), much sinistral in front of anterior testis midway between ventral sucker and hinder end or further in front (Liolopinae and Harmotrematinae), in a dpression on the middle of left border opposite to the side of gonads (Moreauiinae). Gonads in hinder body more or less in the same line or arranged in a triangle (to right side of middle line in Moreauiinae). Ovary between testes, in the same line or lateral to them, rarely partly or completely in level with anterior or posterior testis. Laurer's canal present; receptaculum seminis present or absent, usually small. Testes two in number, behind ventral sucker near hinder end (to right side of middle line in Moreauiinae). Cirrus sac usually vesicular, small or large. Vesicula seminalis outside or within cirrus sac; pars prostatica present, rarely absent; cirrus with or without spines. Vitellaria composed of small follicles, lateral, usually stripe-like extending to hinder end of ovary or end of body (Harmostominae Leucochlorididiinae), lateral and somewhat massive in anterior half (Hasstilesiinae), or extensively developed filling all the available space (Liolopinae, Harmotrematinae, Moreauiinae). Uterus large with numerous small ova (Harmostominae, Hasstilesiinae. Leucochlori didiinae), moderately developed with less numerous large ova (Liolpinae, Moreauiinae), or very short with a few large thick-shelled ova (Harmo-

trematinae). Metraterm present. Ova oval, small, 0·02-0·03* long (Harmostominae, Hasstilesiinae, Leucochloridiidiinae), or very large, 0·105—0·18 long (Liolopinae, Moreauiinae, Harmotrematinae). Free living miracidium absent; parthenitae simple or branched, develop in Pulmonata, produce comparatively a small number of cercariae, which are devoid of stylet, stylet glands, cystogenous cells and a natatory tail. Adolescariae live in snails, adults (maritae) parasitic in reptiles, birds, mammals and exceptionally Amphibia.

Type genus: *Harmostomum* Braun, 1899.

Key to the Subfamilies of the Harmostomidae

1. Genital pore behind posterior testis, subterminal or terminal at hinder end.....Leucochloridiidiinae.
2. Genital pore submedian, behind anterior testis, half way between ventral sucker and hinder end; vitellaria in anterior half..... .....Hasstilesiinae.
3. Genital pore median or submedian, much behind ventral sucker, in the region of testes or a little in front; vitellaria extending to hinder end of ovary or end of body..... Harmostominae.
4. Genital pore on the middle of left border; gonads to right side of the middle line of much flattened and broadened out rectangular body with long axis of rectangle representing the breadth..... .....Moreauiinae.
5. Genital pore much sinistral, in front of anterior testis; vitellaria meeting behind or both behind and in front of testes.....6.
6. Vesicula seminalis outside cirrus sac.....Liolopinae.
7. Vesicula seminalis within cirrus sac.....Harmotrematinae.

Subfamily Harmostominae Braun, 1899.

Synonym.—Heterolopinae Looss, 1899.

Subfamily diagnosis:—Harmostomidae: Body elongated, tongue-shaped, ribbon-shaped or filiform, rarely broad and somewhat oval; cuticle with true or rudimentary spines. Excretory pore at hinder end; lumen of principal excretory vessels ciliated. Genital pore median or submedian,

*All measurements in mm.

ventral, a little in front of hinder end, in the region of testes or a little more forwards. Cirrus sac small, vesicular. Vesicula seminalis small, outside cirrus sac. Cirrus unarmed. Receptaculum seminis present or absent. Vitellaria lateral, usually stripe-like, extending to anterior testis, ovary or hinder end. Uterus large with numerous small ova of 0·02-0·03 length. Parasites of birds and mammals.

Type genus.—*Harmostomum* Braun, 1899 (syn. *Heterolope* Looss, 1899).

Key to the Genera of the Subfamily Harmostominae.

Body long, ribbon-shaped or filiform; ventral sucker feebly developed, much smaller than oral sucker.....A.

Body medium sized, broad, tongue-shaped, band-shaped or somewhat oval; ventral sucker well developed, larger, equal to or a little smaller than oral sucker..... B.

A. Genital pore just in front of or in the region of anterior margin of anterior testis.....*Scaphiostomum.*

Genital pore just anterior to or in region of anterior margin of posterior testis..... *Ityogonimus.*

B. Genital pore behind anterior testis or just in front of posterior testis..... *Glaphyrostomum.*

Genital pore in front of anterior testis or in level with its anterior part..... C

C. Prepharynx muscular, resembling pharynx.....*Entosiphonus.*

Prepharynx tubular and flexible, but not muscular..... D.

D. Cuticle without spines; siphons of excretory bladder extracaecal..... .....*Ectosiphonus.*

Cuticle with spines; excretory bladder intracaecal .... *Harmostomum.*

The genus *Harmostomum* has been divided by Witenberg into two subgenera which are distinguished as follows:—

Oral sucker usually with its opening in the form of a longitudinal slit; genital pore at the level of anterior border of anterior testis or just in front; intestinal caeca straight.....Subgenus *Harmostomum*

Oral sucker with round or transversely oval opening; genital pore usually behind anterior border of anterior testis; intestinal caeca sinuous .....Subgenus *Postharmostomum.*

Subfamily Leucochlorididiinae Proche, 1907

Synonym—.Urogonimimae Looss, 1899.

Subfamily diagnosis:—Harmostomidae: Body tongue-shaped, elliptic, oblong or oval; cuticle smooth or with fine spines; suckers weakly developed or large. Excretory pore terminal or subterminal near hinder end; lumen of principal excretory vessels usually not ciliated. Genital pore terminal at hinder end, subterminal and dorsal, or ventral behind posterior testis, near hinder end. Pharynx small or powerful; oesophagus very short or absent. Testes and ovary nearly in a staight line or arranged in a triangle. Cirrus sac behind gonads, near hinder end. Receptaculum seminis absent or present. Vitellaria lateral, ending in the region of ovary, or posterior part of posterior testis or at hinder end of body. Uterus large, restricted to post-acetabular region, or extending in front of acetabulum, with numerous small ova of 0·02-0·03 length. Parasites of Bursa fabricii and cloaca of birds or small intestine of mammals.

Type genus.—*Leucochloridium* Carus, 1835 (syn. *Urogonimus* Monticelli, 1888)

Key to the Genera of the Subfamily Leucochlorididiinae

Body tongue-shaped; suckers weakly developed..... *Urotocus.*
Body elliptical, oblong or oval; suckers large.....1.

1. Ventral sucker nearer hinder end; anterior testis in front of ventral sucker..... *Urorygma.*
   Ventral sucker near middle of body or in front; anterior testis behind ventral sucker .....2.
2. Genital opening behind posterior testis, ventral, in front of hinder end; gonads nearly in a straight line; uterus not extending in front of acetabulum..... *Panopistus.*
   Genital opening terminal or subterminal and dorsal; gonads arranged in a triangle; uterus extending in front of acetabulum.
   ..... *Leucochloridium.*

Subfamily Hasstilesiinae Hall, 1916

Subfamily diagnosis:—Harmostomidae: Body broad and oval, very small, nearly round in transverse section; cuticle with minute spines; suckers

small, nearly equal. Genital pore submedian, ventral, near anterior border of posterior testis, about half way between ventral sucker and hinder end. Gonads arranged in a triangle. Testes large; posterior testis nearly median in extreme hinder region; anterior testis near middle of body to left side. Ovary small, ventral to right intestinal caecum, near anterior margin of posterior testis. Cirrus sac large, flask-shaped. Vesicula seminalis outside cirrus sac. Receptaculum seminis absent. Cirrus long, unarmed. Vitellaria lateral, semewhat massive in anterior half of body. Uterus large with numerous small ova of 0·013-0·02 length. Parasites of intestine of rabbit (*Lepus*).

Type genus.—*Hasstilesia* Hall, 1916.

Subfamily Liolopinae Cohn, 1902.

Subfamily diagnosis:—Harmostomidae: Body very small, elongated and flattened, sometimes with depressed ventral surface. Suckers with weak musculature. Genital pore much sinistral half way between median line and left body margin, in front of middle of hinder body between ventral sucker and anterior testis. Cirrus sac small. Vesicula seminalis large, outside cirrus sac and in front of anterior testis. Pars prostatica absent. Cirrus armed with spines. Vitellaria extensively developed, from intestinal bifurcation to hinder end, meeting behind posterior testis. Uterus relatively small with a smaller number of coils. Ova less numerous, large and thin shelled. Parasites in the gut of Amphibia (stomach and intestine of *Cryptobranchus japonicus*).

Type genus.—*Liolope* Cohn, 1902.

We remove the genus *Helicotrema* Odhner, 1912 from the Liolopinae to the Harmotrematinae.

Subfamily Harmotrematinae Yamaguti, 1933.

Subfamily diagnosils:—Harmostomidae. Body very small to middle sized, elongated, tongue-shaped or conical; cuticle smooth. Suckers small with weak musculature. Prepharynx absent; pharynx present; oesophagus short; intestinal caeca long, simple, reaching near hinder end. Excretory system characteristic in *Harmotrema*. Genital pore much sinistral, about half way ebtween median line and left body margin (*Harmotrema*) or at

left body margin (*Helicotrema*), pre- or post-equatorial. Cirrus sac large, in front of anterior testis. Vesicula seminalis large, within cirrus sac. Cirrus armed with spines. Vitellaria extensively developed, uniting in front of or both in front of and behind testes. Uterus very short with a small number of large, thick-shelled ova of 0·119-0·18 length and 0·075-0·11 breadth. Parasites of intestine of reptiles.

Type genus.-*Harmotrema* Nicoll, 1914.

Key to the Genera of the Subfamily Harmotrematinae.

Body 20-28 long; genital pore at left body margin; testes and ovary lateral to the side of the genital pore.....*Helicotrema.*

Body 1·6-7 long; genital pore inside or ventral to left intestinal caecum i.e., at about half way between median line and left body margin; testes and ovary not lateral.....*Harmotrema.*

Subfamily Moreauiinae Johnston, 1915.

Subfamily diagnosis:—Harmostomidae: Body much flattened and broadened out, rectangular in shape with the long axis representing the breadth and the short axis the length of the worm; integument thin devoid of spines. Suckers small, nearly equal; oral sucker ventral, near middle of anterior border. Excretory opening in middle of posterior border. Prepharynx absent; pharynx present; oesophagus very short; intestinal caeca annular around the body, U-shaped, terminating near one another on each side of the small excretory vesicle. Genital pore in a depression on the middle of left border. Testes transversely elongated, to right side of median line. Cirrus sac very large. Vesicula seminalis coiled within basal end of cirrus sac; pars prostatica and prostate gland cells well developed; cirrus armed with large, recurved spines. Receptaculum seminis absent; Laurer's canal present. Vitellaria extensively developed, filling up the space between caeca and various borders of body, except around suckers and near genital opening. Uterus mainly in left half; metraterm present. Ova relatively small in number, oval, thin shelled, 0·096-0·111 × 0·069-0·079.

Type genus.—Moreauia Johnston, 1915.

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ON THE PHRAGMÉN-LINDELÖF PRINCIPLE

By P. L. Srivastava

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The main result of the paper is contained in Theor. I, which gives conditions sufficient for $f(z) \equiv 0$. Theor. II is a generalization of a Theorem of Akheyser in as much as the region of regularity of $f(z)$ need only be that within an angle of extent $\frac{2\pi}{\rho}$ instead of the whole plane for $\rho > 1$. Theor. III is a modification of Theor. I, the region of regularity and conditions on the order of $f(z)$ being altered suitably. This leads to a result on the order of identically zero functions.

In this short note I wish to point out that with the help of the results established by Phragmén and Lindelöf in their classical memoir[1] I have been able to establish the following theorems :—

Theorem I. If

(i) $f(z)$ *is a regular function of* $z\,(=r\,e^{i\phi})$ *in an angle of extent* $\frac{2\pi}{\rho}$;

(ii) $f(z) = O\ (e^{Ar^{\rho}})$, *where* A *is a positive constant, throughout this angle ;*

(iii) $|f(z)| < e^{-Br^{\rho}}$, *where* $B > A$, *on any radius vector inside this angle ;*

then $f(z)$ *is identically zero.*

Or, in other words,

If $f(z)$ *satisfies conditions* (*i*) *and* (*ii*), *and is not identically zero, then for every positive number* ϵ, *the inequality*

$$|f(z)| > e^{-(A+\epsilon)r^{\rho}}$$

is satisfied on each vector, issuing from the origin and lying inside the angular region in which $f(z)$ *is regular, for an infinity of points whose limit is infinity.*[2]

From Theorem I we can deduce the following generalization of a theorem of Akheyser[3] :—

Theorem II. If

(iv) $f(z)$ *is a regular function of order* $e^{(1+\epsilon)\, r^{\rho}}$ *in the angle* $|\varphi| \leq \frac{\pi}{\rho}$;

(v) $|f(r e^{\frac{i\alpha}{2\rho}})| < A\, e^{-(\cos\frac{\alpha}{2}+\epsilon)\, r^{\rho}}$,

where $0 < \alpha < \pi$, *for all values of* r, A *and* ϵ *being some fixed positive constants,*

(vi) $|f(r e^{-i\alpha/2\rho})| < e^{(-\cos\frac{\alpha}{2}+\eta)\, r^{\rho}}$, *for every positive number* η, *however small, and* $r > r_0(\eta)$;

then $f(z)$ *is identically zero.*

Akheyser took ρ to be an integer and $f(z)$ an integral function of z. Elsewhere [4] I have shown that the restriction that ρ must be an integer is unnecessary. This theorem shows that, in case $\rho > 1$, $f(z)$ need be regular only inside an angle of extent $\frac{2\pi}{\rho}$, and not in the whole plane.

The next theorem is of the same character as theorem I. In this the angular region in which $f(z)$ is regular is of an extent less than $\frac{2\pi}{\rho}$, but the condition $B > A$ is replaced by $A < -B \cos \alpha\rho$.

Theorem III. If

(vii)) $f(z)$ *is a regular function of* z *in the angle* $|\varphi| \leq \alpha$, *where* $\frac{\pi}{2\rho} < \alpha < \frac{\pi}{\rho}$;

(viii) $f(z) = O(e^{K\, r^{\rho}})$, *where* K *is a positive constant throughout this angle;*

(ix) $f(z) = O(e^{A\, r^{\rho}})$ *on* $\varphi = \pm\, \alpha$, *and*

$= O(e^{-B\, r^{\rho}})$ *on* $\varphi = 0$;

then $f(z)$ *is identically zero, if* $A < -B \cos \rho\alpha$.

As a particular case we have the following result;—

If $f(z)$ *is a regular function of exponential type in the angle* $|\varphi| \leq \alpha$, *where* $\frac{\pi}{2} < \alpha < \pi$, *and is bounded on the vectors* $\varphi = \pm\, \alpha$, *then it cannot satisfy*

the equality $f(z) = O\left(e^{-\delta r}\right)(\delta > ,0)$ *on the positive real axis without being identically zero.*

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NITROGEN FIXATION AND AZOTOBACTER COUNT ON THE APPLICATION OF SUGARS TO THE SOIL

PART II

By N. R. Dhar and E. V. Seshacharyulu

Chemistry Department, Allahabad University.

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Conclusion:—

1. The influence of sunlight on nitrogen fixation and Azotobacter numbers in the soil on the addition of sugars has been investigated.
2. Nitrogen fixation on the addition of sugars is greater in the soils exposed to sunlight than in those kept in the dark, whereas the Azotobacter numbers are much less in the former when compared to the dark ones.
3. The total carbon of the exposed soils is always less than those kept in the dark showing thereby that in presence of sunlight the oxidaton of energy-rich substances is greatly facilitated and causes nitrogen fixation in greater amounts than in the dark.
4. In tropical soils the chemical fixation of nitrogen plays an important part.
5. Sugars are detected in the soil even after long periods.

In a previous paper[1] it has been reported by the present authors that there is no correlation between the Azotobacter numbers and the nitrogen fixation when molasses is added to the field soil. Hence it has been concluded that the fixation of nitrogen in the tropical soils in presence of energy-rich substances may not be entirely a bacterial process as has been hitherto believed. This conclusion is strongly supported by the experimental results recorded in this communication.

Experimental

1000 gms. of garden soil were mixed with 20 gms. of cane sugar or glucose and 300 c.c. of water in enamelled basins and exposed to sunlight daily for seven hours. Some basins with the same substances were kept in a dark room in order to exclude light. In one set of the experiments 2 gms. of calcium

carbonate were added. 160 c. c. of water were addded twice a day to the exposed basins and 160 c.c. of water to the basins kept in the dark after every three days for maintaining an uniform moisture content. Before the commencement of the experiment, estimations of nitrogen, total carbon and Azotobacter numbers of the original soil were done. At regular intervals, the nitrogen content, total carbon and Azotobacter counts of the exposed and dark basins were determined. The total carbon was estimated by the method of Robinson, McLean and Williams [2].

The following results were obtained.

Discussion:—

The experimental results show that although the azotobacter numbers in the basins exposed to sunlight for seven hours daily are much less, the amounts of ammonia and total nitrogen are greater than in those kept in the dark. Moreover the amounts of carbon in the exposed basins are less than in those kept in the dark. Hence in presence of sunlight the oxidation of substances like canesugar and glucose is greatly facilitated and causes the fixation of nitrogen in greater amounts than in the dark. It is clear, therefore, that in the presence of light the photochemical oxidation of energy-rich substances can cause nitrogen fixation just as the bacterial agency does under ordinary conditions. Hence it can be concluded that along with bacterial fixation of nitrogen in tropical soils, there is considerable fixation due to the photochemical oxidation of the energy-rich substances and that is why although the number of Azotobacter in the basins receiving sunlight is much less than in the basins kept in the dark, the ammonia and total nitrogen contents are greater than in the dark ones.

It may be argued that when the basins are exposed to the light, the temperature of the soil is increased and this leads to an increased activity of Azotobacter and hence an increase in the nitrogen fixation. We have measured the temperature of the basins receiving sunlight and this varies from 40^0 - 44^0, whereas the dark room temperature varied from 25^0 - 30^0. In a previous paper Dhar and Tandon[3] have reported that the optimum temperature for Azotobacter is 35^0 and the fixation at 45^0 is practically the same as at 20^0. Hence the nitrogen fixation due to Azotobacter alone should be identical in the basins kept in the dark room or receiving sunlight. In order to test this point further 200 gms. of the garden soil mixed with 2 gms. of glucose and 32 c.c. of water were incubated

at 32°. Another dish with the same substances was exposed to sunlight. To the exposed one 32 c.c. of water were added twice a day and to the incubated one 32 c.c. after every five days. Both the soils were analysed simultaneously on the following dates recorded in the table.

200. gms of soil + 2gms. glucose (Exposed).

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter in millions per 1 gram of dry soil
10-3-1936 (original soil)	0·00108	0·0024	0·042	0·441	1·6	7·2
soil + glucose	–	–	–	0·841	—	—
1-4-36	0·0024	0·0024	0·0446	0·619	2·1	12·5
11-4-36	0·00304	0·0024	0·0456	0·511	2.5	15·7
	200 gms.of soil + 2 gms. glucose				(Incubated)	
1-4-36	0·00186	0·0024	0·0437	0·684	3·6	31·8
11-4-36	0·00214	0·0024	0·0442	0·602	3·9	45·0

The above results show that although the soil is incubated at 32°—33° which is very near the optimum for Azotobacter, yet the ammonia and total nitrogen contents of the one incubated are less than that exposed, whose temperature while receiving sunlight is 42°—44°. It appears, therefore, that the greater nitrogen fixation in presence of light is chiefly due to the photo-oxidation of the energy-rich compounds.

It is of further interest to note that the size of the Azotobacter colonies developed on the plates containing the incubated soil is much bigger than those obtained from the exposed one. Even in the case of the soils kept in the dark, the Azotobacter colonies derived from them are also appreciably bigger than the colonies obtained from the soils receiving sunshine under similar conditions. A tentative suggestion may be offered as to the reason of the difference in size that the generation time of those kept in the dark and also incubated at 32°—33° is less compared to those exposed, probably sunlight inhibiting the growth. If bacterial metabolic activity is considered to go hand in hand with the growth activity, the fixation of atmospheric nitrogen in the incubated and dark basins should have been more than the ones exposed, if no other agent was responsible in nitrogen fixation. The results obtained are contrary to the above. Therefore

in tropical soils apart from bacterial fixation of nitrogen the chemical fixation plays an important rôle.

In recent publications Subrahmanyan and his collaborators[4] have emphasized that under restricted air supply, the sugars from molasses when added to the soil decompose within a few days. Our observations, however, have been different, as we have found that plenty of sugar remains undecomposed even after long periods. Molassed dishes were exposed to sunlight for about a year daily for seven hours. 5gms. of the molassed soil were treated with 2 N potassium chloride, boiled and filtered. Copious reduction of Fehling's solution was observed both with the hydrolysed and unhydrolysed soil extracts. The precipitate of cuprous hydroxide obtained dissolved in a solution of ammonium carbonate forming a clear solution showing the absence of iron and aluminium in the potassium chloride extract along with sugars. Copious reduction of Fehling's solution was also observed when treated with potassium chloride extract of a soil containing 2% glucose and exposed for two months daily for seven hours. It appears, therefore, that the major portion of the sugars added to the soil under ordinary conditions are oxidised to CO_2 and water and this leads to fixation of nitrogen in tropical soils.

An interesting point can be deduced from our observations that the fixation is not much affected by the presence of calcium carbonate. This behaviour is due to the fact that soils with which we carried on our experiments are rich in calcium.

1000 gms. soil + 2 gms. $CaCO_3$ + 20 gms. cane sugar (Exposed)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
30-10-1935 Original soil	0·001236	0·003168	0·0433	0·4677	1·2	12·5
13-1-36	0·00152	0·003168	0·0433	...	...	8·6
30-1-36	0·00215	0·0032	0·0442	1·0356	...	9·3
15-2-36	0·00364	0·0032	0·0488	0·866	...	11·3
29-2-36	0·00464	0·00336	0·0506	0·713	2·2	18·3
16-3-36	0·00552	0·00336	0·051	0·606	2·0	18·8
31-3-36	0·00488	0·00346	0·0506	0·563	2·05	13·2
14-4-36	0·00392	0·0036	0·0506	0·557	1·95	14·6

1000 gms. soil + 20 gms. canesugar (Exposed)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
30-12-1935 Original soil	0·001236	0·003168	0·0433	0·4677	1·2	12·5
13-1-36	0·00143	0·003168	0·0433	...	...	6·0
30-1-36	0·00205	0·0032	0·0442	1·0401	...	7·9
15-2-36	0·0035	0·0032	0·00482	0·866	...	10·3
29-2-36	0·0436	0·00328	0·05	0·718	2·6	19·2
16-3-36	0·00524	0·00336	0·0506	0·602	1·8	18·2
31-3-36	0·00476	0·50344	0·05	0·552	2·1	17·1
14-4-36	0·0038	0·0036	0·05	0·549	2·1	16·2

1000 gms. soil + 2o. gms. canesugar + $CaCO_3$ (Dark)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
30-12-1935 Original soil	0·01236	0·003168	0·0433	0·4677	1·2	12·5
13-1-36	0·00126	0·003168	0·0433	—	—	9·5
30-1-36	0·00157	0·003168	0·0433	1·1383	—	33·7
15-2-36	0·00215	0·003163	0·0456	1·028	—	715·0
29-2-36	0·00288	0·03168	0·00472	0·928	3·85	250·0
16-3-36	0·0032	0·00322	0·0472	0·837	3·2	375·0
31-3-36	0·00372	0·00322	0·0488	0·696	3·4	415·0
14-4-36	0·0036	0·00325	0·0488	0·618	3·1	395·0

1000 gms. soil + 20 gms. canesugar (Dark)

Data	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions
30-12-1935 Original soil	0·001236	0·003168	0·0433	0·4677	1·2	12·5
13-1-36	0·00125	0·003168	0·0433	—	—	7·4
30-1-36	0·00152	0·003168	0·0433	1·1494	—	28·8
15-2-36	0·0021	0·003168	0·0456	1·028	—	170·0
29-2-36	0·00288	0·003168	0·0472	0·922	3·5	245·0
16-3-36	0·00336	0·00325	0·0472	0·832	3·15	365·0
31-3-36	0·0038	0·00325	0·0488	0·698	3·2	420·0
14-4-36	0·00372	0·00325	0·0488	0·614	3·3	400·0

1000 gms. soil + 20 gms. glucose + 2 gms. $CaCO_3$ (exposed)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
4-2-36 Original soil	0·00123	0·003168	0·0433	0·4677	1·3	11·2
22-2-36	0·00168	0·003168	0·0433	1·1734	2·0	10·2
7-3-36	0·0028	0·003168	0·046	1·0014	1·9	18·8
21-3-36	0·00348	0·0032	0·0488	0·836	1·9	17.3
7-4-36	0·0044	0·0032	0·05	0·691	2·1	15·4
21-4-36	0·00372	0·0036	0·05	0·638	2·3	15·8
7-5-36	0·00336	0·00376	0·0488	0·586	2·2	15·1
21-5-36	0·0032	0·00376	0·0488	0·526	2·3	15·6
7-6-36	0·00305	0·00382	0·0488	0·506	2·1	15·0

1000 gms. soil + 20 gms. glucose (exposed)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
4-2-1936 Original soil	0·00123	0·003168	0·0433	0·4677	1·3	11·2
22-2-36	0·00166	0·003168	0·0433	1·1778	2·1	9·9
7-3-36	0·0028	0·003168	0·00456	1·0014	2·0	17·4
21-3-36	0·00336	0·0032	0·0477	0·842	1·8	16·3
7-4-36	0·00452	0·0032	0·05	0·694	2·2	16·8
21-4-36	0·00388	0·00354	0·05	0·642	2·1	16·1
7-5-36	0·00343	0·00382	0·0488	0·591	2·3	16·2
21-5-36	0·00336	0·00382	0·0488	0·521	2·1	16·1
7-6-36	0·003o5	0·0039	0·0488	0·51	2·2	16·5

1000 gms. soil + 2o gms. glucose + 2 gms. $CaCO_3$ (Dark)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total carbon %	Total Nitrogen %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions.
4-2-1936 original soil	0·00123	0·003168	0·0433	0·4677	1·3	11·2
22-2-1936	0·001424	0·003168	0·0433	1·2056	2·95	18·5
7-3-36	0·00168	0·003168	0·0433	1·1232	3·0	36·7
21-3-36	0·00204	0·003168	0·0456	1·0221	3·1	168·0
7-4-36	0·00258	0·003168	0·0466	0·906	3·2	232·0
21-4-36	0·0029	0·003168	0·0466	0·8074	3·5	315·0
7-5-36	0·00329	0·0328	0·0472	0·6127	3·3	390·0
21-5-36	0·003	0·00325	0·0472	0·6127	3·2	365·0
7-6-36	0·0029	0·00328	0·0472	0·5636	3·0	325·0

ERRATA.

Vol. VI. Part III, page 248, Table (Exposed).

1. Line 4, against 15-2-36 under column Total Nitrogen, read 0·0482 for 0·00482.
2. Line 5, against 29-2-36, under column Ammoniacal Nitrogen, read 0·00436 for 0·0436.
3. Line 7, against 31-3-36, under column Nitric Nitrogen, read 0·00344 for 0·50344.

Table (Dark).

1. Line 1, against Original Soil, column Ammoniacal Nitrogen, read 0·001236 for 0·01236.
2. Line 4, against 15-2-36, under column, Number of Azotobacter per gm. of dry Soil in millions, read 175·0 for 715·0.
3. Line 5, against 29-2-36, under column Nitric Nitrogen, read 0·003168 for 0·03168, and under column Total Nitrogen read 0·0472 for 0·00472.

Vol. VI. Part III, page 250, Table (Exposed).

1. Line 3, against 7-3-36, under column Total Nitrogen, read 0·0456 for 0·00456.

Table (Dark).

1. In the columns heading read Total Nitrogen for Total Carbon, and Total Carbon for Total Nitrogen.
2. Line 7, against 7-5-36, under column Nitric Nitrogen read 0·0032 for 0·0328, and under column Total Carbon read 0·6748 for 0·6127.
3. Line 8, against 21-5-36, under column Nitric Nitrogen, read 0·00328 for 0·00325.

100. gms. soil + 20 gms. glucose (Dark.)

Date	Ammoniacal Nitrogen %	Nitric Nitrogen %	Total Nitrogen %	Total carbon %	Moisture content %	Number of Azotobacter per gm. of dry soil in millions
4-2-1936 original soil	0·00123	0·003168	0·0433	0·4677	1·3	11.2
22-2-36	0·0014	0·003168	0·0433	1·2016	3·0	18.0
7-3-36	0·00164	0·003168	0·0433	1·1224	3·1	37.8
21-3-36	0·0021	0·003168	0·0456	1·021	3·2	170.0
7-4-36	0·00254	0·003168	0·0466	0·908	3·3	228.0
21-4-36	0·0028	0·003168	0·0466	0·8078	3·6	320.0
7-5-36	0.00323	0·0032	0·0472	0·6662	3·2	395.0
21-5-36	0·003o5	0·00325	0·0472	0·6088	3·3	350.0
7-6-36	0·00294	0·00328	0·0466	0·5546	3·2	345.0

References

(1) Dhar and Seshacharyulu, *Proc. National Acad. Sci. India* 1936, **6**, 99

(2) Robinson, McLean and Williams, *J. Agric. Sci.*, 1929, **19**, 315.

(3) Dhar and Tandon, *Proc. National Acad. Sci., India* 1936, **6**, 35

(4) Bhaskaran and Subrahmanyan. *Proc. Indian Acad Sci.* 1936 **3** 143

STUDIES ON THE FAMILY BUCEPHALIDAE (GASTEROSTOMATA), PART II. DESCRIPTIONS OF TWO NEW FORMS FROM INDIAN MARINE FISHES

By S. C. Verma

Zoology Department, Allahabad University

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Two new species of flukes, one belonging to the genus *Bucephalus*, and the other to *Prosorhynchus* are described from two Marine Fishes of the Bay of Bengal.

The present paper is a continuation of "Studies on the Family Bucephalidae (Gasterostomata), Part I," in which descriptions of a number of new species, from fresh water fishes of India, were given (Verma, 1936). It deals with two new species, from the marine fishes of the Bay of Bengal. The specimens were preserved in Bouin's Picro-formol, to which a little Acetic Acid had been added, and stained either in 1·5% solution of Haemalum or diluted Borax Carmine. Both stains, on differentiating with weak Hydrochloric Acid, gave equally good results.

1. **Bucephalus jagannathai** n. sp.

Description:—A dozen representatives of the worm were found in two out of three fishes of the species, *Cymbium guttatum* (Bl. and Schn.) dissected by me, on the West Coast of the Bay of Bengal, a few miles away from Puri, in December 1935. The parasites inhabit the hinder part of the intestine, and are nearly colourless in the living state, except for two dull-red patches marking the yolk glands. The eggs are yellow and, in one or two places, so densely packed as to impart a brownish yellow tinge to the part of the body containing them. The following account is based on one of the two preparations mounted on the type slide, which is deposited in the collection of the Zoological

Survey of India, India Museum, Calcutta, No. W3316/1. The other preparation (stained with Haemalum) is somewhat contracted and the neck rather twisted; but it displays the cephalic tentacles more beautifully than the Carmine-stained type specimen.

The body is somewhat elongated and cylindrical, but not uniformly thick. It is 1·59* long and 0·42 across in the widest part, which occurs in the region of the ovary. Anteriorly to this region, the body tapers gradually into the narrow front end, but posteriorly it is broadly rounded. The sucker is subterminal, and roughly ovo-elongate in outline, with a shallow scoop-like cavity. It measures 0·168 × 0·11 and bears, along its margin, the very characteristic crown of six tentacles, radiating out at right angles to the main axis of the body. The tentacles are highly extensile and visible, in their natural condition, only in the living parasite or in very well-preserved examples. Each tentacle has its distal end curved backwards, and carries an inwardly directed short process, often feebly knobbed, arising from a point slightly more distal than the middle of the tentacle. The cuticle, on careful examination, under the High Power of a Microscope, is seen beset with extremly fine spines completely embedded in it. Tho spines extend over the greater part of the surface.

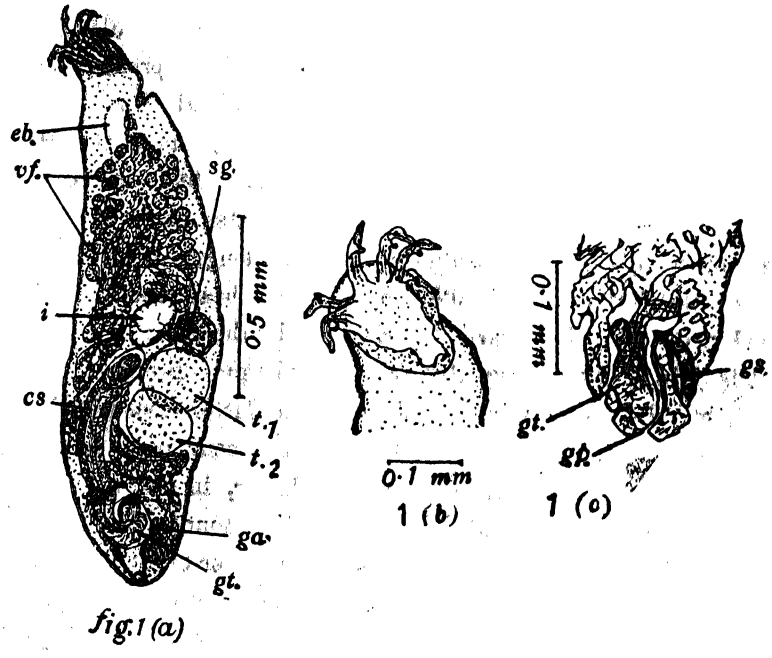
The mouth opens close behind the middle length of the animal and, in the type, its anterior margin is 0·81 behind the head end. The pharynx is feebly developed, globular, partly overlapped by the ovary and 0·067 in diameter. It is joined by an equally long oesophagus, directed antero-dorsally to the short, broadly obovate, intestinal sac. The latter measures 0·151 × 0·117 in size. As the oesophagus and the intestine are bent upon one another like an inverted U, the former is masked by the latter, in dorso-ventrally pressed specimens, and therefore not easily visible in entire mounts.

The ovary is globular, with an average diameter of 0·117. It is situated along the postero-lateral border of the intestine and completely overlaps the shell-gland complex which lies dorsal to it. The relatively large vitelline follicles, with an average diameter of 0·048, are conspicuous in the living worm because of their brick-red colouration. They are distributed, in the lateral fields, from about 0·336 behind the anterior extremity to near the level of the cephalic margin of the intestinal sac. The number of follicles on the ovarian side is fifteen, but on the opposite side it is seventeen. The uterus fills the space between other organs and extends, along the dorsal field, from near the

*All measurements are in millimeters

hind end to the anterior level of the the vitellaria. The eggs are broadly oval in appearance and measure 18μ to 19μ in length and 12μ to 13μ in breadth. They are of a more or less uniform size throughout the uterus; but those in the terminal part of the uterus differ from those in the commencing part of it, by the greater thickness of their shells, and the intensity of colouration.

The testes are almost ovoidal in outline and lie close behind the ovary. The anterior testis partly overlaps ths ovary and is, in turn, overlapped by the posterior testis. It has a dimension of 0·168 × 0·201 and it is located 0·924 behind the anterior end of the parasite. The posterior testis measures 0·168 × 0·170 in size and it is placed somewhat internal to the anterior one, 0·378 ahead of the terminal end. The comparatively long cirrus sac is curved like a sickle, with its concavity facing the the testes, so as to accomodate them



Key to letters used in Figures—:*cp*, cirrus pouch; *eb*, excretory bladder; *ep*, excretory pore; *ga*, genital atrium; *gp*, genital pore; *gt*, genital tongue; *m*, metraterm: *o*, ovary; *p*, pharynx; *s*, sucker or rhynchus; *sg*, shell glands; *vf*. vitelline follicles.

Figure 1. a–c. *Bucephalus jagannathai* n.sp.

a. Ventral View of an entire specimen.

b. Cephalic part of same, showing tentacles.

c. Vertical section from a series showing the protruding genital tongue.

within the anterior half of its length. From the genital atrium the cirrus sac extends forwards to the level of the anterior margin of the first testis, and it is 0·38 long. Enclosed within it are the thin-walled, simple, vesicula seminalis (0·109 × 0·084), pars prostatica, and prostatic cells -all well developed as is usual in the genus. The genital tongue or papilla is conspicuous and nearly fills the genital atrium. The latter has a diameter of about 0·168 aud lies 0·126 further from the nearest body end. The atrium communicates with the ventro-terminal genital pore by a funnel-shaped sinus. The muscular genital tongue is capable of being protruded beyond the pore. This is effected partly by its own elongation and partly by the contraction of the sphincter muscles surrounding the atrium and the sinus, more or less in the same way as recently described *in Bucephalus garuai* (Verma 1936). A section of part of a worm showing the genital tongue thus extruded is sketched in Figure 1, c.

The excretory bladder is a simple tube extending from the terminal pore to some distance behind the sucker (Fig. 1 a, eb).

Variations:– In fixed specimens the sucker varies, in form, from scoop–shaped to oval according to its state of expansion, at the time of fixation. In rare cases it is nearly rounded. In fact, in four of the ten individuals examined, the sucker was like that of the type specimen (Fig.1 a.): in four others it had a perfect scoop–shaped appearance. Only in two specimens the sucker presented a nearly circular outline, as can be seen on the second preparation on the type slide. The two vitel–larial fields, in the majority of forms, display unequal levels. The follicles on the ovarian side extend more forwards and less backwards than those on the other side. Only in one preparation, the vitellaria, on the side of the ovary, ran further posteriorly than those on the opposite side–three follicles being overlapped by the ovary. In the tyye speci–men, however, the usual, unequal extent of the vitelline follicles of the two sides is not so marked. Some variation was also observed in the relative position of the gonads and their sizes, in pressed mounts. The former may have been caused by unequal pressure exerted on different flukes during the process of flattening, and the latter may be due to differences in their respective ages. In eighty per cent of the preserved specimens, the anterior testis is more outwardly placed than the posterior, and is slightly the larger of the two: only occasionally the two gonads are of about equal dimensions. But in one of the ten trematodes seen, the hinder testis is distinctly bigger than its fellow,

The ovary is usually overlapped by the first testis to some extent; but in some cases the two organs are just contiguous.

Discussion:– The parasite above described is easily distinguished, from all the known species of the genus *Bucephalus* to which it clearly belongs, by the number and form of its cephalic tentacles. The only other forms of the genus with tentacles having a single lateral process are *B. carangis* (MacCallum, 1917) and *B. polymorphus* Baer, 1827. But both of these flukes have seven tentacles instead of six of the species under discussion. Further, in *B. carangis* the tentacles are ramified at ends, and in *B. polymorphus* the lateral processes arise at a level different from that in the form above described. In addition to the above clear distinctions, this Indian representative differs from others of the genus in the size and shape of its body and also in its internal anatomy. It is therefore considered new and designated after the famous temple at Puri as *B. jagannathai*.

Specific diagnosis of *Bucephalus jagannathai* n. sp. :—*Bucephalus* Baer, 1927. In balsam mounts 1.1-1.7 long by 0·42-0·54 broad, in region of ovary or intestine: sucker shallow, ventro-terminal, usually scoopshaped, 0·166-0·193 × 0·11-0·17: cephalic tentacles six, each 0·7-0·9 long and 0·016-0·017 broad near middle, where it gives off a short lateral process: pharynx equatorial, feeble, partly or wholly overlapped by ovary and shell glands, 0·17 in diamater: intestine saclike, short, 0·151-0·17 × 0·117-0·126 in size, bent over oesophagus: gonads packed together, usually overlapping one another, mostly in third fourth of body: ovary 0·42-0·84 in diameter, lateral to intestine, near commencement of third quarter of body: uterine coils from near genital atrium to anterior level of vitellaria: vitellaria lateral, at somewhat unequal levels, in second quarter of body; follicles large, rounded, 0·042-0·058 in diameter, in number 14-15 on the ovarian side, 16-17 on the other: testes larger than ovary, partly overlapping one another, along inner side of anterior half of cirrus sac: anterior 0·18-0·23 in diameter, in close contact with ovary or slightly overlapping it; posterior smaller than or nearly equal to anterior: cirrus sac 0·38-0·55 × 0·08-0·11, sickle shaped, about one third as long as body, to level of front margin of anterior testis: genital atrium 0·126-0·18 in diameter, 0·09-0·134 ahead of hind end: genital tongue well-developed, muscular, protrusible beyond genital pore: genital pore ventroterminal, leading into atrium by short sinus: excretory bladder broadly tubular,

to midway between vitellaria and sucker; pore postero-terminal: eggs numerous, light to deep yellow, broadly oval, 0·0186-0·0199 × 0·0116-0·0133. In lower intestine of spotted mackerel, *Cymbium guttatum* (Bl. and Schn.), Bay of Bengal, near Puri.

2. **Prosorhynchus truncatus** n. sp.,

Description. Two specimens of this trematode were obtained from the intestine of *Arius jatius*, a small fish, dissected at Puri, Bay of Bengal. One of these, the mature one, got smashed in an attempt to press it so as to render visible any filaments on the eggs. Fortunately, this happened after the dimensions of the worm and the eggs had been noted. The following description is therefore based on a single specimen in which the eggs are not yet developed.

The worm has an elongate, cylindrical, body more than four times as long as thick. The sides are nearly parallel, except for a constriction in the oesophageal region. At the anterior end is a truncated rhynchus with its broader margin in front, while the posterior extremity is rounded and less broad than the opposite end. In length the fluke measures 1·76 and in maximum breadth, which lies at the level of the pharynx, 0.42. The mature specimen which was crushed measured 2·6 long and 0.6 broad. Fine cuticular spines barely projecting beyond the surface adorn the greater part of body surface. The anterior sucker or rhynchus is triangular in outline, with the apex directed inwards, and measures 0.25 across, being about as long as broad.

The pharynx is globular and situated at about one third the body length from the hind end. It is 0.15 in diameter and its actual distance, from the two extremities to the nearest margin, comes to 1.02 and 0·59 respectively. A cluster of gland cells, full of yellowish granules, is clearly visible along the front margin of the pharynx, and another along its hind border. The oesophagus is about 0.084 long and nearly two-thirds as broad. It is short and dilates into a forwardly directed saccular intestine 0.46 × 0.3 in size. The intestine is shaped very much like a balloon and reaches to within 0·51 of the head end.

The female as well as the male gonads lie along the right side of the body. The ovary lies close to the lateral wall of the body, on same level as the mouth opening. It is separated from the pharynx

by a space equal to the diameter of the posterior testis, but is in close contact with the antero-lateral border of the anterior testis. It is smaller than the testis and, probably owing to the worm being immature, it measures only 0.06 in diameter: but in the adult specimen lost, it was half as big as the adjacent male gonad. The shell glands form a compact oval mass, between the two testes, which is of nearly same size as the ovary, and lies along the same longitudinal line as the latter. The vitellaria consist of twentynine, small, rounded, follicles 0.017-0.02 in diameter. They are arranged in a semi-circle, along the anterior curve of the intestine. The follicles do not extend backwards beyond the middle level of the intestine.

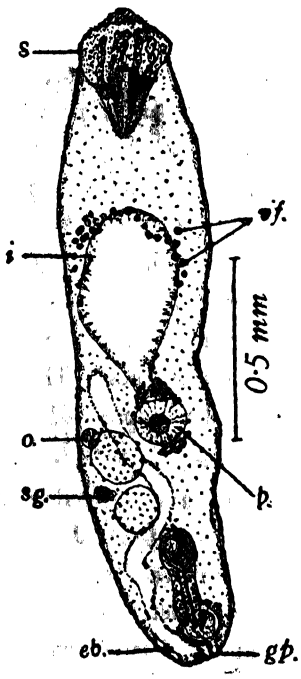


fig. 2

Fig. 2. *Prosorhynchus truncatus* n. sp.

Ventral view of an immature specimen.

The testes occur one behind the other, somewhat obliquely in the third-fourth of the body. The anterior is situated just postero-internal to

the ovary with its long axis oblique. It is ovoidal in outline and measures 0·151 × 0.134. The posterior testis is separated from the anterior by a narrow gap and is slightly smaller but more rounded than it. It is 0·134 in diameter. The cirrus pouch is short, thickly built, 0·33 long by 0·08 wide, and extends inwards to the level of the hind margin of the posterior testis. The part enclosing the vesicula seminalis is broader than the part containing the pars prostatica. The genital atrium is also broader than the cirrus pouch proper; so that the cirrus sac, with the genital atrium, presents a dumb-bell shaped appearance. The genital papilla or tongue is, as usual in gasterostomes, muscular and occupies the atrial cavity. Surrounding the atrium is a dense cluster of unicellular gland cells. The genital pore lies at the end of a short conical passage leading from the atrium towards the ventro-posterior end.

The excretory bladder takes the form of a sinuous, tubular, structure extending forwards to about the middle of the body, as indicated in Figure 2, eb. It opens externally by a minute terminal aperture close behind the genital pore.

The eggs measured 35μ-40μ by 18μ-20μ, in the specimen lost.

Discussion. From the foregoing account of the fluke and the diagnostic key of the species of the genus *Prosorhynchus* given by Eckmann, 1911, it is evident that the form above described is new to science. The worms included by Eckmann in his key, *P aculeatus* = *P. squamatus* Odhner, 1905, *P. crucibulus* (Rudolphi, 1919) and *P. facialis* Ozaki, 1924 are all readily distinguished from the Indian species by their body form and size, and by the relative size and position of the testes, the vitellaria, the intestinal sac and the cirrus pouch. Eckmann has, however, not included in his paper *P. grandis* Lebour, 1908 and *P. uniporus* Ozaki, 1924. Both the latter named species also differ materially from the parasite under discussion, in body shape and size as well as in the relative disposition and size of internal organs, particularly so in the more forward location of the vitellaria, the ovary and the intestinal sac of the above described species. *P. uniporus*, the Japanese representative, is further differentiated from the Indian form by the position of its testes which lie on opposite sides of the cirrus sac. Therefore the parasite in discussion is new and named *Prosorhynchus truncatus*, but its specific diagnosis is reserved until more material is available.

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THE PHOTO-REDUCTION OF FERRIC CHLORIDE IN ALCOHOLIC SOLUTIONS IN THE LIGHT OF A QUARTZ MERCURY VAPOUR LAMP

By Mata Prasad and B.V. Mohile.

Royal Institute of Science, Bombay

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The order of the reduction of ferric chloride by organic substances in presence of light has been studied by various workers. Winther and Oxholt–Howe (Z.Wiss. Phot., 7, 409, 1909; 8, 197, 1910; 9, 205, 1911) found that the photo–reduction of ferric chloride by organic acids is zero molecular. Benrath (Jour. Prakt. Chem., 80, 283, 1909) studied the reduction by measuring the densities of the solutions exposed to light. On calculating the ratios of $\triangle/t$ where $\triangle$ represents the change in density in time t, for different intervals, he found that the reaction is zero-molecular. But looking to the complex mechanism of the reaction proposed by Benrath it is difficult to see how the changes in the density values of the reaction mixture can give a correct idea of the amount of reduction of ferric chloride in a given interval of time.

The order of the photo–reduction of anhydrous ferric chloride in various anhydrous alcohols was studied by Prasad and Sohoni (J. Indian Chem. Soc., 8, 489, 1931) in artificial light and they found that the reduction tends to reach a stationary state after some time. Prasad and Liamye (J. Indian Chem. Soc., 10, 91, 1933) studied the reduction in sunlight and in artificial light for an interval beyond that crorresponding to the stationary stage. They found that the reduction proceeds in two stages and the order of both stages of reduction is zero-molecular in artificial light. Further they found that the velocity of reduction in the second stage of the reaction is slower than that of the first. These authors made several attempts to find if any change takes place in the

solution after the first stage of the the reduction is completed, to account for the second stage of the reaction but no conclusive evidence could be obtained.

In the present investigation the photo-reduction of ferric chloride dissolved in various alcohols has been studied in the light from a quartz mercury vapour lamp. The influence of the concentration of solutions of ferric chloride on its rate of reduction in artificial light has also been determined.

Experimental

The source of light used was a quartz mercury vapour lamp placed inside a wooden box with a quartz lens and a variable resistance and an ammeter were placed in series with the lamp.

The solution of ferric chloride was exposed to the radiation in an optical cell of quartz of 5 mm. internal thickness.

B.D.H. anhydrous ferric chloride A.R. was used and it was dissolved in anhydrous alcohols which were either Merck's or Kahlbaum's extra pure chemicals.

The amount of reduction was measured by Knopp's method (Jour. Amer. Chem. Soc. 46, 263, 1924)

The following concentrations of hydrochloric and phosphoric acids and of the indicator were used in the present experiments.

(1) One part of concentrated hydrochloric acid was mixed with two parts of concentrated phosphoric acid the whole was diluted to three times its volume. 10 c.c. of this mixture were used for each titration.

(2) 8 drops of 0·008 M. solution of diphenylamine in concentrated sulphuric acid were used for each titration.

The total volume of the titration mixture was made up to about 60 c.c. The presence of alcohols in the mixture necessitated a small correction to be applied, which was determined by making a blank experiment with the unexposed solution. Also a correction was made for the amount of dichromate required to oxidise the indicator.

Solimbo and Rothe (Rev. Brassil Chem. Soc., 129, 49, 1928) have shown that the presence of mercury and tin salts does not affect the end point of the titration. Hence the above method was used for the estimation of the initial concentration of ferric iron in the solution by

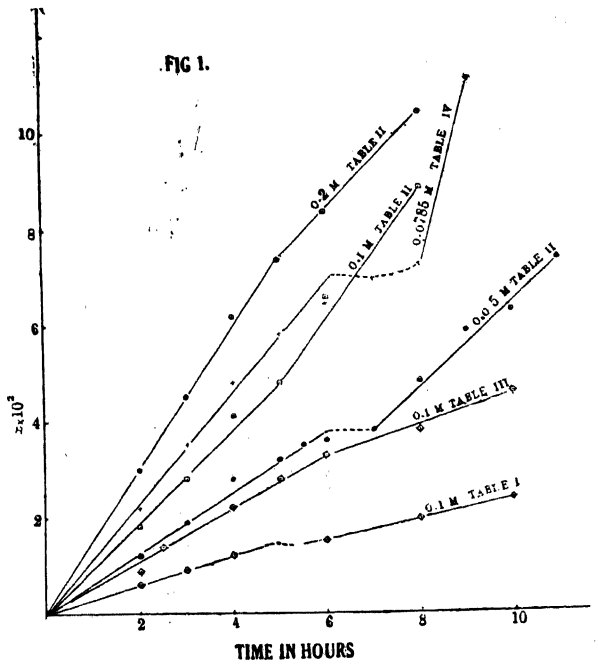
first reducing the solution with stannous chloride and removing the excess of it by mercuric chloride.

The titrations were carried out by washing the cell thrice and the washings were transferred to the titration bottle.

The action of light takes place on those layers of the solution which are nearer to the source of light in preference to those away from it. To avoid this action of internal filter and the consequent inhomogenity of the reaction mixture the thickness of the cell was made small and the solution was gently shaken from time to time (*cf.* Ghosh and Purkayastha J. Indian Chem. Soc., 6, 827, 1929), during exposure to light.

The results obtained are given in the following tables in which the first row gives the time t in hours, the second, the reduction X in millimols of $FeCl_3$ in 3·5 c.c. of solution and the third, K, the zero-molecular constant, calculated for the unit of time expressed in minutes.

In all cases X-t curves have been drawn; some of these are single straight lines while others, particularly those corresponding to dilute solutions (*Cf.* Fig 1.), are made up of two straight lines. For the



calculation of K for points lying on the second of the two straight lines the values of X and t, referred to those marked with an asterisk in Tables

as zero, have been used. In cases where the two straight lines meet at points marked with the asterisk, the values of K for such points have been calculated as in the case of other points lying on the first straight line.

TABLE I

Methyl Alchol

Conc. of $FeCl_3 = 0{\cdot}1$ M.

t	2	3	4	6*	8	10
$X \times 10^2$	0·6	0·9	1·2	1·5	1·9	2·3
$K \times 10^2$	0·005	0·005	0·005	—	0·0033	0·0033

TABLE II.

Ethyl Alcohol

Conc. of $FeCl_3 = 0{\cdot}05$ M.

t	2	3	4	5	5·5	6	7*	8	9	10	11
$X \times 10^2$	1·2	1·9	2·8	3·2	3.5	3·6	3·8	4·8	5·9	6·3	7·4
$K \times 10^2$	0·010	0·0105	0·0117	0·0107	0·0106	0·0100–		0·0167	0·0175	0·0139	0·0150

Conc. of $FeCl_3 = 0{\cdot}1$ M

t	2	3	4	5*	6	8
$X \times 10^2$	1·8	2·8	4·1	4·8	6·6	8.9
$K \times 10^2$	0·0.50	0·0155	0·0171	0·0160	0·0300	0·0228

Conc. of $FeCl_3 = 0.2$ M

t	2	3	4	5*	6	8
$X \times 10^2$	3·0	4·5	6·2	7·4	8·4	10·5
$K \times 10^2$	0·0250	0·0250	0·0258	0·0247	0·0166	0·0172

TABLE III

n—Propyl Alcohol

Conc. of $FeCl_3 = 0{\cdot}1$ M

t	2	2·5	4	5	6*	8	10
$X \times 10^2$	0·9	1·4	2·2	2·8	3·3	3·8	4·6
$K \times 10^2$	0·0075	0·0093	0·0092	0·0093	0·0092	0.0042	0·0054

Conc. of $FeCl_3 = 0.2$ M

t	2	3	4	5	6	8
X × 10^2	2·1	3·3	4·0	5·2	6·7	8·3
K × 10^2	0.0175	0·0183	0·0167	0·0173	0·0186	0·0173

Conc. of $FeCl_3 = 0{\cdot}3$ M

t	2	3	4	5	6
X × 10^2	3·1	4·4	6·1	7·0	8·0
K × 10^2	0·0258	0·0244	0·0254	0·0233	0·0222

Table IV

n—Butyl Alcohol.

Conc. of $FeCl_3 = 0{\cdot}0785$ M

t	2		4	5	6	7	8*	9
X × 10^2	2·2	3·5	4·8	5·8	6·5	7·0	7·3	11·2
K × 10^2	0·0183	0·0194	0·0200	0·0193	0·0180	—	—	0·0650

Conc. of $FeCl_3 = 0{\cdot}157$ M

t	2	4	5	6	7	8
X × 10^2	2·7	5·5	6·7	7·7	8·9	10·7
K × 10^2	0·0225	0·0229	0·0223	0·0214	0·0212	0·0223

Conc. of $FeCl_3 = 03{\cdot}M$

t	2	3	4	5	6	8
X × 10^2	3·4	5·0	6·3	7·8	9·4	11·9
K × 10^2	0·0283	0·0278	0·0262	0·0260	0·0261	0·0248

The above data shows that the reduction follows a zero-molecular order. The values of the zero-molecular constant also show that there are two values which are fairly constant among themselves. Prasad and Limaye (loc. cit.) also found that there are two values of the zero-molecular constant and that the X-t curves are made up of two straight lines. Benrath (loc. cit.) who also studied the course of the reaction for nearly 8 hours did not notice the change in the mode of reaction as the solutions he used were 0·2 N and 0·25N in which case the solutions tend to give a single straight line.

Effect of Concentration

On exposing solutions of different concentrations, c, (3 gms. in 50 c.c. to 3 gms. in 3200 c.c. or 0·4 N to 0·0065 N. approximately) to light Beurath determined the time t required for their complete decolorisation and found that c/t is constant i.e.-dc/dt, the rate of reduction, is independent of the initial concentration of the solution. Some experiments were, therefore, made to examine the effect of initial concentration on the rate of reduction of ferric chloride.

The arrangement of the apparatus was similar to that described before. The source of light was a 1000 Watt Cinema projector lamp of the vertical type. The back of the lamp was specially coated with a silver mirror so as to increase the intensity of the incident radiation. A glass cell containing a concentrated solution of alum was used to screen off the heat radiations. 3·5 c.c. of the solution were exposed in a glass cell for 15 minutes and the amount of reduction was determined as described before. The results obtained are given in the following tables in which X carries the same meaning as before and c represents the initial concentration in molality of $FeCl_3$.

TABLE V.

Solution in Ethyl Alcohol

C	0·0286	0·0572	0·1144	0·1710	0·229	0·286	0·342	0·400
$X \times 10^2$	3·4	5·0	5·9	7·1	7·7	8·2	8·5	8·5

TABLE VI.

Solution in n-Propyl Alcohol

C	0·0286	0·0572	0·1144	0·1710	0·229	0·286	0·342	0·400
$X \times 10^2$	2·1	3·6	5·0	5·6	6·1	6·6	7·0	7·3

Table VII

Solution in n-Butyl Alcohol.

C	0·020	0·040	0·060	0·080	0·171	0·286	0·342	0·400
$X \times 10^2$	2·3	3·0	3·65	4·2	5·5	6·8	6·8	6·8

On the assumption that the amount of reduction is proportional to time for all the concentrations used in these experiments the values of $= dx/dt$ (the rate of change in concentration, expressed in moles per litre, per minute) have been calculated and have been plotted against c.

This assumption is justified on the consideration that the X-t curves for the first stage of the reaction are straight lines. It will be seen from the $(c, -\frac{dx}{dt})$ curves that the velocity of reduction increases with an increase in the initial concentration of the solution and is not proportional to it. It is evident, therefore, that the absorption of light by the solution is not proportional to its iron content. At some concentration the rate of reduction reaches a maximum value; beyond this concentration it (rate) undergoes no change with an increase in the initial concentration of the solution. This is also indicated by the fact that c,-dx/dt curves, at this stage, run parallel to the c axis. Benrath's observations, therefore, hold true only for those concentrations of the ferric chloride solutions which correspond to the parallel part of the above named curves.

The rate of reduction of solutions of ferric chloride in alcohol is thus a function of the initial concentration, c, for what may be called dilute solutions and is independent of c for the concentrated ones. In the latter tase $-dx/dt = k_0$ where k_0 is a constant.

The curves for the rate in the former case are found to obey the relation

$$-\frac{dx}{dt} = kc^n$$

where K and n are constants. Tables VIII, IX and X give the values of $-dx/dt$ calculated from the above equation along with the observed ones. It will be seen that the agreement between the two values is better for the concentrated than for the dilution solution (excepting solution in n-butyl alcohol) in which case the calculated values are greater than the observed ones. These differences may be accounted for by taking the variation in the absorption of light with tbe concentration of solutions into account.

TABLE VIII.

Ethyl Alcohol

$$-\frac{du}{dt} = 0{\cdot}2140\ C^{0{\cdot}262}$$

C	0·0286	0·0572	0·1144	0·1710	0·2290	0·2860	0·3420
$-\frac{dx}{dt} \times 10^2$ (obs)	0·0648	0·0952	0·1124	0·1352	0·1467	0·1562	0·1619
$-\frac{dx}{dt} \times 10^2$ (cal.)	0·0843	0·1011	0·1213	0·1348	0·1454	0·1542	0·1615

TABLE IX.

n–Proply Alcohol

$$-\frac{dx}{dt} = 0.1849 \quad C^{0\cdot308}$$

C	0·0286	0·0572	0·1144	0·1710	0·2290	0·2860	3·3420	0·4000
$-\frac{dx}{dt} \times 10^2$ (obs)	0·0400	0·0545	0·0952	0·1067	0·1161	0·1257	0·1333	0·1390
$-\frac{dx}{dt} \times 10^2$ (cal)	0·0619	0·0766	0·0948	0·1074	0·1174	0.1257	0·1328	0·1394

TABLE X.

n–Propyl Alcohol

$$\frac{dx}{dt} = 0\cdot2154 \quad C^{0\cdot4065}$$

C	0·030	0·040	0·060	0·080	0·171	0·286
$-\frac{dx}{dt} \times 10^2$ (obs.)	0·0438	0·0590	0·0695	0·0800	0·1047	0·1295
$-\frac{dx}{dt} \times 10^2$ (cal.)	0·0439	0·0582	0·0683	0·0771	0·1051	0·1295

Chemical Laboratories
Royal Institute of Science,
Bombay.